NATIONAL
SOCIETY FOR CLEAN AIR

(Formerly National Smoke Abatement Society)

FUMUS FUGETUR

Proceedings of the Hastings Conference 1957

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The Society's Publications

This is one of the many publications of the National Society for Clean Air. For a complete list write to the Society for its current Year Book. This contains a Guide to Publications on Smoke Prevention and Allied Subjects, which lists, in addition to the Society's own titles, particulars of other books, reports and papers, including Government reports, any of which may be purchased from the Society. The list is classified according to subject—the Law, Conference Proceedings, General, Historical, Smoke Prevention Administration, Industrial Smoke, Domestic Heating, Technical and Scientific, and Industrial Pollution.

NATIONAL SOCIETY FOR CLEAN AIR

(*Formerly National Smoke Abatement Society*)

Proceedings of the 24th Annual Conference

Hastings

2nd to 4th October, 1957

Palace Chambers, Bridge Street, London, S.W.1.

CONTENTS

Index to Contributors 4

Summary of Events 5

Presidential Address:

The Primary Sources of Pollution, by Dr. R. Lessing 7

Address by the Minister of Power, Lord Mills, K.B.E. 13

Air Pollution from Road Vehicles

Operation and Maintenance to Minimize Pollution, by H. E. Styles and A. T. Wilford 15

The Law and its Enforcement, by James R. Archer-Burton 25

Discussion 32

The Administration of the Clean Air Act, 1956

Some Points on its Practical Application, by M. Lindsay Taylor .. 38

A Critical Survey, by G. Graham Don 41

Report on the Availability of Smokeless Fuels 46

Discussion 50

Industry and the Clean Air Act

How Industry Views the Clean Air Act, by L. A. W. Jenkins .. 58

Fuel Efficiency and Clean Air, by Angus Macfarlane 65

Discussion 70

The Des Vœux Memorial Lecture

Meteorology and Air Pollution, by Sir Graham Sutton, C.B.E... .. 77

Conference Resolution

Statement on the Training and Qualification of Boiler Operators .. 87

INDEX

To Authors and Participants in Discussion

Page

Archer, A. 74
Archer-Burton, J. R. 25

Barnes, Cllr. H. W. 35
Bate, W. 55
Batey, J. W. 33
Burn, Dr. J. L. 32

Carr, N. 55

Dale, V. W. 32
Don, G. Graham 41
Driver, F. A. 55
Duguid, S. N. 36, 73

Gibbons, Cllr. E. 73
Goulden, Ald. G. H. 72

Jenkins, L. A. W. 58, 75
Johnson, H. 74

Lessing, Dr. R. 7
Lister, D. 35
Longhurst, F. E. 52
Lowbridge, H. E. T. 56

Page

Macfarlane, Dr. A. 65, 76
McGlashen, R. 36, 52
McGrath, W. R. 51

Marsh, A. 46, 56
Mills, Lord 13

Newsholme, Cllr. C. C. .. 74

Piddington, Cllr, S. C. 52
Prendergast, Ald. Mrs. A. E. .. 73

Raper, Cllr. D. 56
Rylands, J. R. 70

Smith, G. C. 34
Steel, T. 75
Styles, H. E. 15, 36
Sutton, Sir Graham 77

Taylor, M. Lindsay 38, 50
Tomlins, Dr. F. G. 33
Turner, Dr. W. C. 55

Watson, C. A. 53
Wilford, A. T. 15
Winfield, E. J. 54, 74

SUMMARY OF EVENTS

Once again the Conference was attended by a record number of members and delegates: 717 as compared with 679 in 1956 and 578 in 1955. The meetings were held in the White Rock Pavilion by invitation of the Mayor and Corporation of Hastings.

The opening session on the Wednesday morning included a welcome by the Right Worshipful the Mayor of Hastings, Alderman F. T. Hussey, J.P., the Presidential Address by Dr. R. Lessing, and an address by the Minister of Power, the Rt. Hon. Lord Mills.

With Dr. J. S. G. Burnett in the chair, the Wednesday afternoon session was concerned with air pollution from road vehicles. Two papers were read, by Mr. H. E. Styles and Mr. A. T. Wilford of the London Transport Executive, and by Mr. James R. Archer-Burton, Chief Constable of Hastings. During the evening delegates attended a most enjoyable reception in the Pavilion, by invitation of the Mayor and Mayoress.

The Chairman for the Thursday morning session was given in the programme as Mr. John Innes, but in his absence because of illness his place was taken by Mr. James Goodfellow. The subject of the session was the administration of the Clean Air Act, with papers by Mr. M. Lindsay Taylor, Town Clerk of Tottenham and Mr. Graham Don, of the London School of Hygiene and Tropical Medicine, followed by a report on the availability of smokeless fuels, prepared for the Executive Council by Mr. Arnold Marsh, Director of the Society.

Dr. T. P. Colclough, Chairman of the Society's Technical Committee presided over the Thursday afternoon session in the absence of Sir Ernest Smith, whose name had been given in the programme. Papers were presented on the Clean Air Act and industry, by Mr. L. A. W. Jenkins, speaking as an industrialist, and Dr. W. A. Macfarlane, Chief Executive of the National Industrial Fuel Efficiency Service. The discussion was opened by Mr. John R. Rylands, President of the Institute of Fuel.

On the Friday morning the Des Voeux Memorial Lecture, on " Meteorology and Air Pollution," by Sir Graham Sutton, F.R.S., Director-General of the Meteorological Office, was read. In Sir Graham's absence abroad on official business the Lecture was presented by Mr. P. J. Meade, also of the Meteorological Office.

The lecture was followed by the annual general meeting, at which the re-election of Dr. R. Lessing, as President, was announced, together with the re-election of existing Vice-Presidents and four new ones: Alderman Dr. C. A. Bence, Mr. Eric Gibbons, Mr. John Innes and Mr. F. J. Redstone. The Conference heard with the deepest regret that owing to ill-health the Honorary Treasurer, Sir Ernest Smith, had found it necessary to resign from that office. The meeting agreed to authorize the Executive Council to appoint an Acting Hon. Treasurer until the next elections. A formal resolution was passed authorizing the dissolution of the Society and the transfer of its assets to the new, incorporated, National Society for Clean Air, on 31st December, 1957, or such later date as might be necessary.

A conference resolution, recorded in this volume, on the training and qualification of boiler operators, was also adopted.

An invitation, from the Chairman of the Council, to hold the 1958 Conference in Llandudno on 1st, 2nd and 3rd October was read, and its acceptance by the Executive Council was endorsed by the meeting.

A general vote of thanks, proposed by Mr. T. Henry Turner, was carried with acclamation. In addition to the speakers, authors and chairmen mentioned above, it referred also to the Mayor and Corporation of Hastings, Councillor G. H. Tanner, B.E.M., Chairman of the Hastings Hygiene Committee, Mr. A. K. Vint, Publicity and Public Relations Officer, Hastings, the manager and staff of the White Rock Pavilion, Mr. A. J. Cousin, and the staff of the Society.

The Presidential Address

The Primary Sources of Air Pollution

by

R. Lessing

Ph.D., F.R.I.C., F.Inst.F., F.Inst.Pet., M.I.Chem.E., M.Inst.Gas.E.

To one who has devoted much of his working life to the objects at which this Society aims it is a matter of particular gratification to be considered worthy of occupying its presidential chair. I am sensible of the great honour and I tender my sincere thanks for the confidence you place in me.

Many of the Presidential Addresses of my predecessors have struck a historical note to demonstrate that air pollution is an evil of long standing, some going back to Queen Eleanor who was " smoked " out of Nottingham in 1257, exactly 700 years ago. The extensive literature ranging from John Evelyn's " Fumifugium " to the current issues of *Smokeless Air*, if it has not achieved the desired results, has at least successfully established one all important point. It has furnished incontrovertible proof that air pollution is " a bad thing ".

This badness being axiomatic I do not propose to review the long and detailed catalogue of woe and misery, of calamitous incidents, futile reports of committees, and dead-letter legislation, but rather look into the future to see what can and should be done to eradicate the evil.

But I feel constrained to depart in one respect from my intention not to delve into the past. I believe that I owe my election to the Presidency more to my long connection with the Society and one of its parent bodies, than to any other attainment. This connection may justify a brief retrospect by an eye-witness of the growth of the movement during almost a half-century.

Recollections

Looking at the composition of Council and Executive Committee of the Coal Smoke Abatement Society, one could hardly conceive of a more influential body of men of the highest standing in public life. There was however an almost complete absence of technologists. The first President, Sir William Richmond, was a painter; the Treasurer and champion of the movement, Dr. H. A. Des Voeux, a medical man; and the Secretary, Mr. (later Sir) Lawrence W. Chubb, an administrator who had gained his organizing experience as the first Secretary of the National Trust.

This combination resulted in the activities of the Society being directed mainly to telling the public about the effects of " smoke " on amenities, health and property, and attempting to bring offenders to book on the strength of the law inadequate as it then was. The work of the Society under the last heading suffered a grievous set-back in 1907, when a summons served by the Chelsea Borough Council upon Underground Electric Railways Limited in respect of smoke emission from Lots Road Generating Station, was dismissed by the Magistrate, Mr. Curtis Bennett, on the ground that the smoke was not black.

Endeavours to get the law amended were pursued under Chubb's wise counsel. Meanwhile the Society's one and only inspector observed the smoke of London. His reports of nuisances were submitted to the boroughs concerned resulting in varying degrees of action or inaction.

One was forced to the conclusion in those early days that complaints were of little avail until the fuel consuming public, both industrial and domestic, were instructed and had learned why and how smoke was formed and how it could be avoided or minimized. This implied a knowledge of the fuel. Realizing that consumers should know something about their fuel, I submitted a paper to the Conference of Representatives of Local Authorities held at the Sheffield Smoke Abatement Exhibition in March 1909, on "The calorimetric control of the Supply and Combustion of Fuel", a subject which at that time had received little attention in this country. This was the Conference which gave birth to the Smoke Abatement League of Great Britain.

Under the auspices of the Coal Smoke Abatement Society the first international Smoke Abatement Conference was held in connection with the Exhibition at the Agricultural Hall, London, in March 1912. Twenty-eight papers were read, some of them by Delegates from abroad. The Conference, of which I had the privilege of being the Honorary Secretary, marked a milestone in the investigation of air pollution. For at its conclusion a resolution was passed

> "That immediate steps should be taken to decide upon and secure the general adoption of a standard method for the measurement of atmospheric pollution by smoke and other products of combustion and heat, in order that the data now being collected may possess a comparative value, and that a Committee be appointed to draw up details of a standard soot and dust measuring apparatus and methods of its use."

In due course the Committee for the Investigation of Atmospheric Pollution was established on a voluntary basis, and is still continuing as the Atmospheric Pollution Research Committee under the D.S.I.R. I have the melancholy distinction of being one of the only three surviving members of the original Committee, the others being Sir John Russell, F.R.S., and Lord Simon of Wythenshawe. A small working group consisting of Sir Napier Shaw, F.R.S., the eminent physicist and then Director of the Meteorological Office, Dr. H. A. Des Voeux, Dr. J. S. Owens and myself met very informally in each other's homes to prepare the ground for the investigation.

The first experimental deposit gauge originally constructed by Dr. Owens for the "Lancet" series of tests was installed on the roof of my laboratory in High Holborn, to settle the details of the analysis of the deposits. They proved the great importance of the estimation of tarry matter. It furnishes a telling distinction between domestic and industrial emissions. Indeed, a close statistical treatment of the vast number of observations collected during the last forty years, now facilitated by modern electronic computers, would settle the ever-recurring controversy regarding the ratio of pollutants derived from the two main groups of fuel usage. A system based on this distinction might permit a useful check of results obtained from smoke control areas.

The Clean Air Act

After this historical excursion, albeit into a period within living memory, I shall cast my eyes into the future. I do not mean to do this as a wishful visionary but on the strength of conclusions drawn by closely studying the trend of the fight against air pollution.

The Beaver Committee has taken stock of the situation and the Clean Air Act 1956 is the law of the land. The critics may not consider it perfect and some cynical doubters may apply to it Ben Jonson's view of one of his untrustworthy characters:

" If he were
To be made honest by an act of parliament
I should not alter in my faith of him."

The general approval accorded to the Act shows a more generous attitude and indicates that it is a workable measure. Already, during the first nine months of operation of the Act 30 local authorities have submitted proposals for smoke control areas for government approval.

Matters affecting the administration of the Act have been discussed at length at the Society's conferences and divisional meetings and in other places. It is a truism to say that the law can, in reason, only be enforced if the means to comply with it are readily available.

Let us now inquire whether and to what extent these means are available. The first sentence in the Beaver Committee's outline of the problem in its Interim Report reads: " Sufficient is known already about the causes, effects and cure of air pollution to enable the broad problem to be appreciated, measured and largely tackled."

The Committee's Final Report after an intensive and fairly exhaustive investigation, has pin-pointed causes and effects and has based its recommendations for a cure on measures considered to be technically feasible. These recommendations are too well-known to need repetition, but the technical fundamentals upon which they are based will bear some further and more detailed examination.

By and large, the practical steps to overcome the nuisance, already taken or recommended, may be summarized as:

Providing suitable plant and appliances for combustion of fuels

Using methods of burning fuels efficiently and completely

Providing equipment for extracting pollutants from combustion gases before these are emitted into the atmosphere.

The principles governing these steps are well-known. Much work has been done over the years to elaborate design, operation and methods of control and this work has been greatly intensified since air pollution has reached the headlines of the popular and technical press, following the great London smog of 1952.

What remains to be done now in regard to the combustion engineering side of the problem, is the all-round application of the apparatus and its effective working. The hope may be justified that the recognition of the damage caused to property and health will gradually dawn on the general public and that common sense, stimulated in the last resort by the Clean Air Act, will induce the British public to help in clearing the air it breathes.

Now, being an incorrigible optimist, I will assume that the fuel-using community, householders and industrialists alike, will play their part, will be willing and co-operative in modifying or installing plants and appliances of technically sound construction and will work and maintain them satisfactorily. There, then, still remains one all-important factor which was omitted from my brief list of requirements. I refer to the fuels supplied.

The Fuel

Whilst it is up to the consumer to install or maintain equipment for combustion and flue gas treatment, possibly aided by the grants prescribed in the Clean Air Act and by other fiscal means, he has only a limited choice of heating agents. He may safely opt for gas or electricity, but for the kind, type or quality of solid or liquid fuels, he is in the hands of the suppliers, i.e. the National Coal Board or the oil companies.

Unlike the mechanics of fuel usage those properties of coal and oil which inevitably affect the production of pollutants, the *primary sources of air pollution*, have in the past not received that attention and study in their relation to our problems which their importance deserves.

I will deal first with coal which for a long time will be our staple fuel, though supplemented with oil and nuclear energy. How do specific properties or components of coal influence the formation of smoke, grit and dust, sulphur oxides?

Smoke. Potentially the liability to smoke formation depends on the type or " rank " of coal. Whatever its rank with the exception of anthracite and low volatile coals, " raw " coal is bound to produce smoke in the open domestic grate and in badly designed, incompetently stoked and overloaded boiler furnaces. Smoke prevention here can only be effected in modern appliances, well operated and maintained.

The nature of the primary product of the mines cannot be changed, and all the National Coal Board can do in this regard is to organize distribution on rational lines, to meet the reasonable requirements of each group of consumers.

A true solution of the domestic problem demands the replacement of house coal in open grates by smokeless fuel or the installation of modern appliances. In industry the 40,000 handfired boiler furnaces must be fitted with or replaced by mechanical stokers suitably instrumented and competently operated.

The economic advantages to be gained will accelerate this development with increasing rapidity.

Grit and Dust present a different problem. It inherently resides in the coal as supplied. It mainly, though not entirely, affects the industrial fuel user.

It is my contention that a large, if not the major portion of grit and dust discharged from the country's chimneys is derived from the " natural " dust in coal. It is obvious from aerodynamical principles that this fine dust is lifted from a fuel bed and entrained by the fire gases, in form of ash, incompletely burned and carbonized particles. " Natural " dust is contained in mined coal at the rate of 10 million tons a year and its proportion is steadily rising with the ever increasing production of fines.

If the National Coal Board could be persuaded to incorporate de-dusters in their coal preparation schemes, by no means a novelty in this country, the problem of dust arresting on thousands of boiler plants would be eased and emission diminished. By pneumatic de-dusting of coal prior to washing the slurry nuisance will be abated. Moreover, the burning of slurry results itself in appreciable dust emission, whilst the product from de-dusters will find a satisfactory outlet in pulverized fuel plants.

Natural dust plays a minor part when the whole coal is ground to powder, but in this case another problem arises. In 1923, when the introduction of pulverized fuel plants in this country was discussed, I uttered a warning against the replacement of the vanishing smoke nuisance by a steadily growing flue dust nuisance. Today we have very efficient cyclones and electrostatic precipitators, but the quantity of coal fired in powder form has risen to well over 20 million tons a year mainly used in power stations. Even with an extracting efficiency of 99 per cent.—by no means generally achieved—more than 100,000 tons of flue dust escape into the atmosphere. To reduce this amount and incidentally lighten the load of the precipitators, a substantial portion of the high ash should be removed at the colliery from the " untreated smalls " used by power stations and other large works to an ever increasing extent.

Sulphur. The avoidance of pollution of the air by sulphur oxides is perhaps the most intractable subject we have to consider. The difficulty and expense of extracting them once they are formed have militated against a general adoption of methods for flue gas treatment. Let us see what could be done at the source.

We must reluctantly admit that the sulphur inherent in the pure coal substance cannot be removed, except partially in the carbonizing process. However by appropriate preparation a substantial portion of high sulphur refuse can be washed out from the raw coal.

Take as an example the electricity generating industry's annual fuel budget which, including oil and foreign coal, now exceeds 40 million tons, containing in round figures 600,000 tons of sulphur. The major portion of the coal consists of " untreated smalls " which contain more sulphur and have a lower calorific value than the remainder, comprising graded and washed sizes.

By relating the sulphur content to the heating value, it becomes apparent that in the " dirty " half the ratio ranges from 0·17 to 0·4 pounds sulphur per Therm compared with 0·1 to 0·15 pounds sulphur per Therm in the other half. In other words, however low the price per ton may be, the purchaser of " untreated smalls " buys sulphur at the sacrifice of calorific value. By eliminating the worst of the high-sulphur material from one half of the coal the sulphur dioxide emitted would be reduced by 250,000 tons, i.e. one quarter of that estimated by the Beaver Committee for Electricity Works.

Any amelioration achieved on these lines will pro rata dispose of the flue gas washing problem.

The steady increase in smalls, ash and sulphur in mined coal, unavoidable for well known reasons, makes the more extensive and more intensive cleaning, particularly of " untreated smalls," all the more necessary. I offer no excuse for reiterating this theme. I cannot accept the customary objection that " it is uneconomic " since the recovery of the heat value and sulphur from the washery discard has been made possible by modern means.

The need for reducing the sulphur is pressing, not only where coal itself is burned, but equally so in coal supplied to the carbonizing industries. Although in the manufacture of solid smokeless fuels sulphur is removed with gas, tar and liquor, that fixed in the coke or semi-coke remains about the same ton for ton as in coal.

In the production of gas coke and low-temperature coke the removal of sulphur at the colliery has the added advantage of a lowering of the ash. The drive for a wide domestic use of smokeless fuels will succeed only if the housewife's daily chores are eased.

Sulphur in Oil. The expansion of the use of fuel oil involves a considerable addition to sulphur oxides pollution. Of the distilled fractions of petroleum, petrol is substantially free from sulphur. Diesel and gas oils are relatively low in sulphur with a ratio of 0·1 pound sulphur per Therm. Recently desulphurization of such oil coupled with recovery of elemental sulphur has rapidly progressed. One might expect that the oil refining industry, with its great research and development resources and its experience of catalytic processes, would contrive to find practical ways and means for the extraction—and recovery—of sulphur from their residual oils, which now contain up to 4 per cent. and tend to show higher sulphur percentages in the future.

I have enlarged on sulphur as a source of pollution because its acidic compounds are responsible for more material and bodily damage than any other impurities in the air. The material damage is undoubted. More than two-thirds of the £152·5 m. worth of direct damage given by the Economic Sub-Committee of the Beaver Committee and already known to be an under-estimate is due to sulphur.

The effects on health are still under active and, in the absence of adequate facts, sometimes controversial discussion. For the causation of lung cancer which has lately aroused lively public interest, organic compounds in smoke and engine exhausts are blamed. The Medical Research Council found that, whilst on balance it seems likely that atmospheric pollution plays some part in causing the disease, it is only a minor one in comparison with cigarette smoking.

Whatever the final outcome of these investigations, the carcinogenic substances involved are not primary sources which are the subject of this address, but are decomposition products of these formed by incomplete combustion.

On the other hand, bronchitis and allied respiratory diseases, even if not initially caused by sulphur dioxide are aggravated by it and particularly by the sulphur trioxide and sulphuric acid into which it is inevitably converted. The tragic results of the 1952 London smog and the general incidence of bronchitis in Britain which is higher than in other European countries afford a close correlation with the sulphur pollution of our atmosphere.

Prevention v. Cure

The health aspect leads us to draw an important analogy. From the beginning of this century medical science and practice has undergone a decisive switch from curative to preventive medicine. The time has come to promote a similar transfer of emphasis in the field of air pollution. We should seek out the sources, prevent the potential pollutants from reaching the points of fuel utilization and thus diminish, if not avoid, the need for curing the evil at the end of the chain of operations.

The Society

I said at the outset that I proposed to cast my eyes into the future, and I hope to have indicated certain fundamental facts which will require more consideration for the solution of the problems facing us than they have received in the past. The recognition has slowly but surely been gaining ground that air pollution is not restricted to visible smoke. The decision of the Society will therefore be welcomed, that in applying for incorporation, it should change its name to the *National Society for Clean Air*. This development is highly significant for two reasons. Firstly the Government approved constitution enhances the status of the Society, and secondly, the more comprehensive title widens its scope and sets new tasks.

The Society can look with pride at the results it has achieved by patient and unremitting work over many years. It has steadily gained in prestige and may now be regarded as a truly national institution.

This has been brought about with a minimum of financial resources. To carry on its good work effectively and to meet the demands in the epoch we now enter, it must rely on the support of all concerned with the implementation of the Act and air pollution in general, industry both private and publicly owned, local authorities and, not least, H.M. Government.

In asking for financial support, the Society need not appear *in forma pauperis;* it can almost claim such support as a prescriptive right. Has it not richly earned a reward for its labours and those of its precursors, the Coal Smoke Abatement Society and the Smoke Abatement League of Great Britain, during a period of sixty years? The voluntary work of the early pioneers has laid the foundation on which the Government's Atmospheric Pollution Research Committee have based that massive fund of observed facts the like of which no other country possesses.

By its discussions, publications, advice and services, and by peaceful persuasion of authorities and individuals, our Society can justly claim to have prepared the ground for the effective working of the new legislation. It deserves all the material help needed to maintain its useful position as an independent body ever watchful of developments, and to strengthen it for the tasks ahead. Let those in the Society's debt come forward to honour their obligations.

Address

by The Minister of Power, Lord Mills, K.B.E.

IT gives me great pleasure to be with you at this Conference this morning and it gives me particular pleasure to be with your President, Dr. Lessing. Dr. Lessing is, if you will forgive my saying so, one of the grand old men of the Clean Air movement. His association with the Coal Smoke Abatement Society of London began nearly half a century ago, and even before that he was already engaged on research and consulting work of great importance for clean air. He is expert in many aspects of the problem, and long may this Society and the country as a whole enjoy the benefit of his wisdom and experience. I was very interested on looking at the Conference programme to find that, of the first fourteen Conferences, all but two were held in towns situated in what have become known as the " black areas " and that, of your last ten Conferences including this one, all but one have been in " white areas." I wondered whether this change in location combined with the proposed change in the name of your Society to which your President has referred, signifies a change in your policy. Whether, in short, you will in the future lay more stress on the benefits of smokeless air than on the evils of air pollution?

If your policy is to give your delegates a practical demonstration of what clean air means, then you have done well to choose Hastings for your meeting place this year. I very much hope that before many years are out you will be able to hold your Conferences in a town that is clean, not because—like Hastings—it has always been clean, but because its atmosphere has been successfully cleared through the operation of our clean air policy. I think this would be a triumphant justification of the work your Society has been doing for so many years and should serve as a great inspiration to all those concerned with air pollution to press ahead with the completion of their task.

As Minister of Power I am vitally interested in the success of the clean air policy, because the main way to clean air is by increased fuel efficiency. I have a dual purpose in that I have to do my best to see that fuels are produced in the right quantities and the right qualities to meet the demands of industry, commerce and the domestic consumer, and at the same time I have to see that they are used as efficiently as possible. It is indeed fair to say that there can be no hope of cleaner air in our cities unless people are prepared in the future to use their fuel more efficiently and more sensibly than they have in the past.

I have said before and I don't mind saying again that I am appalled at the way in which we waste our fuel resources, and in particular at the way in which we waste our most precious asset, coal. I realize that our wasteful habits are a survival from the days when we had cheap and plentiful supplies of fuel in this country. Those days are past, fuel is no longer cheap and our experience since the war has indicated all too clearly that it is no longer plentiful in the sense that we have more than we require for our immediate needs. And yet people continue to waste coal.

To a certain extent I can understand although I do not condone, why many industrialists are still not using fuel as efficiently as they could do. The reason for this is that in many cases fuel costs form so small a part of the cost of production as a whole. But I would have thought in these days of rising costs that industrialists would have been prepared to seize upon any means of reducing costs, no matter how marginal they might be in each particular case, and I would have hoped that they would have had sufficient feeling for the financial interest involved to have made a determined effort to use their fuel more efficiently.

Many of you will have seen the Third Progress Report recently published by the National Industrial Fuel Efficiency Service. It contains an illuminating analysis of the work of heat and power surveys that had been carried out by N.I.F.E.S. qualified engineers, and it is stated that savings of between seven and ten million tons of coal could be achieved every year by industry. Figures like these cannot be easily overlooked, and what is particularly interesting is that a substantial proportion of this saving could be achieved not as a result of massive capital investment but merely by improving boilerhouse operation alone.

Then there is the domestic consumer. You know when you think how bitterly any increase in the price of coal is resented and criticized by the average domestic consumers and yet the majority of them continue to burn their coal at an appallingly low efficiency in old-fashioned open grates. Usually when one buys an expensive item of domestic equipment one justifies the expense by saying that " I will be able to get a lot of use out of it." Surely one would have thought that the domestic consumer would not be satisfied merely to complain about the price of coal, but would do everything he could to use what he regards as a very expensive commodity as efficiently and as well as he could.

I hope that I have not given you the impression of being unduly pessimistic about fuel efficiency but, at the same time, I hope that my remarks will have reminded you that it is not an easy task that you have before you. It is one thing to pass legislation for clean air but it is quite another to implement it successfully. What then, are the keys to successful implementation?

First and foremost I would suggest education of the consumer. When I say education I mean information and not exhortation. You must always remember that you are in a battle against tradition and prejudice, and it will require a great effort to overcome them. What is required is a continuous presentation of the facts to consumers, showing them how they can get better value for their money by using their fuels more sensibly. I am sure that in the long run a practical approach to this problem will secure for you the interest of the consumer. There is already a lot being done in this field by bodies such as the National Industrial Fuel Efficiency Service, the Coal Utilization Council, the Solid Smokeless Fuels Federation and the women's organizations. Their services are available to local authorities to help them overcome the problems connected with smoke control areas, and I sincerely hope that they will take every advantage of the services that are available.

The second thing is for industry and the domestic consumer to use the right type of appliance. Here the Government is giving direct assistance to help consumers to increase their fuel efficiency. For industrialists there is the Government Loan Scheme, which provides capital for approved fuel saving schemes, and loans amounting to £4½ million have already been approved; and investment allowances are available as a measure of tax relief for the installation of certain types of fuel saving equipment. As far as the domestic consumer is concerned, the Clean Air Act provides for grants to be paid where smoky grates have to be replaced. Most of them will no doubt be replaced by coke burning fires. Even the simple types of these fires have a higher efficiency than coal fires and will therefore help to save fuel but I hope, however, that in choosing new appliances householders will, in their own interests, consider whether it would not be worthwhile to install the newer and still more efficient types of fire which are now available.

The third key, of course, to the successful implementation of the Clean Air policy is the availability of smokeless fuels in the right qualities and the right quantities. The Clean Air Act has come into force at a time when stocks of coke are exceptionally high. This has come about for a variety of reasons including the unusually mild weather last winter, but it does mean that local authorities, in planning their first smoke control areas, can feel assured that sufficient fuel will be available, indeed there appears to be little doubt that there will be ample smokeless fuels for all the smoke control areas that are now coming forward.

The prospects are also good for the period further ahead. Fortunately the flexibility of the fuel industries is such that they should be able to produce substantial additional quantities of smokeless fuels at fairly short notice and without the need to embark on major programmes of additional capital investment. This is particularly true of both the gas industry and the electricity industry whose present plans should make it possible to supply increased quantities of fuel to smoke control areas.

In the long term there is no doubt that new investment will have to be undertaken by the fuel and power industries to meet the requirements of the clean air programme. I am sure that the industries whose responsibility it is to produce the right type of fuel for clean air will be watching very closely the progress that is made and will be ready to adjust their operations and their capital programmes in whatever way may be necessary.

But it is not enough that smokeless fuels should be available. They must also be acceptable. After all, if you are trying to wean people away from their existing habits you have got to make the alternative as attractive as possible. I have therefore stressed to the industries concerned the need for ensuring that the smokeless fuels they supply must be of the highest quality. What is wanted, for example, is a fuel at a reasonable price which can stand up to ordinary use in the tender care of the ordinary householder. I am sure that the fuel industries are giving this problem the attention it deserves.

In conclusion I would like to say that the passing of the Clean Air Act has not meant that either the Government or your Society can sit back and congratulate itself on having done everything necessary to achieve clean air. There are still many problems to be overcome and much work, and in particular much education of the public, to be carried out. It must, of its nature, be a gradual process. It is not a process, in my view, that lends itself to some master plan dictated from above by the Government. Successful implementation, I would suggest, depends upon the gradual adaptation, on the one hand, of the tastes and habits of the fuel-consuming public of this country and, on the other, of the production of the right sort of fuels to meet the new demand as it emerges.

The task of educating public opinion is great, and in this your Society has an important part to play. The present clean air campaign in the North West of England which I was glad to open in Manchester last month, is a good example of the valuable work your Society is doing. There is bound to be resistance to the development of clean air, but I feel that as long as the facts are fully explained to the public and that they are brought to realize how great will be the advantages of clean air, they will respond readily to the lead you are giving. Above all they must be made to realize that clean air can only be achieved by a personal effort, that this is a case where it is not possible to sit back and expect the other chap to do the job. We are most of us responsible, in one way or the other, for polluting the atmosphere and, this being so, each of us has a part to play and bad habits to alter. If we succeed in enlisting the co-operation of the public in this way the time will surely come when our towns and cities will lie "All bright and glittering in the smokeless air."

Air Pollution from Road Vehicles

(1) THE OPERATION AND MAINTENANCE OF ROAD VEHICLE ENGINES TO MINIMIZE POLLUTION

by

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Introduction

Amongst the amenities of our present civilization the road vehicle powered by an internal combustion engine takes a very high place. It enables the mass transportation of people to and from their work and the conveyance of goods to the remotest village anywhere in the country. It also provides both public and private transport for pursuits of leisure—visits to places of entertainment or interest, week-end outings, tours and holidays. It is not surprising that the number of vehicles in use continues to grow.

The latest available figures for current licences show that there are some 1,130,000 light and heavy goods vehicles, 78,000 buses and coaches, 24,000 taxis and 3,900,000 private cars on the roads of Great Britain at the present time. The number is increasing at the rate of about 10 per cent. each year.

Private cars and light vans are powered by a spark-ignition engine, commonly known as a petrol engine. Heavy goods vehicles and the great majority of buses and coaches are powered by a compression-ignition engine, usually referred to as a diesel engine. Diesel engines of appropriate horsepower are also being increasingly used for goods vehicles of medium size and for taxis; they are also available for private cars, but for reasons which need not be discussed in this paper, they are not likely to replace the petrol engine in this application for many years ahead, if at all.

Fuels Used

Both the spark-ignition engine and the compression-ignition engine use fuels derived from the distillation of crude petroleum oil. The fuels consist essentially of a mixture of hydrocarbons, i.e., chemical compounds which contain only hydrogen and carbon. The fuels differ, however, in respect of volatility, the petrol used by the spark-ignition engine being considerably more volatile than the Derv oil used by the diesel engine. The latter grade of fuel is technically described as a gas oil but is specially selected having regard to its suitability for use in a high speed diesel engine. The name under which it is marketed, Derv, denotes its purpose (fuel for *D*iesel *E*ngined *R*oad *V*ehicles). Derv fuel has a much higher boiling range than has petrol and in the distillation of the crude oil is produced when the petrol, white spirit and kerosene (or paraffin) fractions have been removed. It is, however, important to remember that gas oil itself is a distillate fuel and beyond it in the distillation process are the light and medium lubricating oils before we come to the residual products which, according to the nature of the crude, may be either heavy lubricating oils or medium and heavy fuel oils such as are used either in slow speed diesels or as boiler fuels.

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Combustion Products

If the fuels contained nothing other than hydrocarbons, and if the design and mode of operation of the engines could be such that perfect combustion of the fuel was obtained, the exhaust products discharged into the air would consist entirely of water vapour and carbon dioxide gas together with nitrogen and, possibly, unchanged air. Even so there would be some pollution of the atmosphere in that the proportion of carbon dioxide normally present in the air (0·04 per cent.) would be locally increased and the oxygen content decreased by an amount dependent upon whether the vehicle was being run in an enclosed space or not, the size of the engine and the distance from the exhaust pipe at which a sample was taken. It must, however, be accepted that carbon dioxide will always be generated and oxygen consumed unless indeed we are prepared to forgo the benefits of the internal combustion engine altogether.

There may, of course, be some who will say that air pollution from motor vehicles could be reduced by using electrically propelled vehicles in certain applications, forgetting that the combustion of coal necessary for the generation of electricity also adds to the pollution of the atmosphere. In fact, the replacement of motor vehicles by electrically propelled vehicles would increase the overall pollution of the atmosphere for the reason that the use of electricity generated from coal for the propulsion of a vehicle is a less efficient process than direct production of power through the medium of an internal combustion engine, this being particularly true if the engine is of the diesel type.

Carbon dioxide and water are not the only products of complete combustion of either solid or liquid fuels; both contain sulphur compounds. The amount present in normal petrol is negligibly small. Derv fuel may, however, contain up to 1 per cent. of sulphur, though in some localities fuel containing as little as 0·1 per cent. is in limited supply; London Transport and certain other operators also are using fuel with a sulphur content of about 0·5 per cent. The desirability of reducing the sulphur content of Derv fuels is generally recognized but it is a matter for the fuel supplier rather than the user for the reason that the sulphur can only be removed by a refining treatment of the distillate. It may be noted that at least one large refinery has installed plant for this purpose, the recovered sulphur being a valuable by-product, but it is not commercially feasible to get rid of all the sulphur by refinery treatment.

As already mentioned, there is no sulphur problem associated with petrol. As normally marketed this fuel does, however, contain a small proportion of Ethyl fluid, consisting essentially of tetra-ethyl lead, together with chlorine and bromine compounds, the purpose of which is to prevent the accumulation of lead deposits in the engine exhaust system. The exhaust emission from petrol engines will therefore contain traces of lead and halogen compounds.

Atmospheric pollution derived from compounds (other than hydrocarbons) which are inherently or necessarily present in motor fuels is, however, of less importance than that which arises from incomplete combustion of the fuel, and in cases of gross neglect of maintenance, from emission of vaporized lubricating oil. With the petrol engine, incomplete combustion of the fuel leads to the emission of the toxic gas, carbon monoxide. Indeed, it is not possible to run the petrol engine at maximum efficiency without producing significant amounts of carbon monoxide. In the case of the diesel engine, carbon monoxide accompanied by dense black smoke is only produced when the engine is being operated in an inefficient manner. The reason for this difference will be explained in the next section of the paper.

With both types of engine, the exhaust products will usually contain traces of aldehydes and oxides of nitrogen, the latter being derived from the nitrogen present in the atmosphere. The actual amounts of these compounds—normally expressed in terms of parts per million—vary according to conditions of operation. The compounds are objectionable from the physiological aspect, but the resulting pollution of the atmosphere is probably insignificant in that threshold levels of toxicity are seldom if ever reached. Exceedingly small amounts of polycyclic hydrocarbons—in this case estimated in terms of micrograms per one hundred cubic metres—are also produced, but recent work relating to diesel engines has shown that when efficiently maintained and operated, the amounts introduced into the atmosphere are insignificant compared with those derived from the combustion of coal in domestic fires and commercial premises.

Salient Features of " Petrol " and " Diesel " Engines

An internal combustion engine, whatever its type, is essentially a device for converting into useful mechanical energy part of the heat energy released by chemical reactions which occur when fuels undergo combustion in air. This conversion is achieved by making use of the fact that, when heated, a gas expands or, if prevented from doing so, develops an increased pressure.

There are several ways in which such gaseous expansion or pressure rise can be made to perform useful work, but for road transport purposes reciprocating piston engines have hitherto remained supreme. Such engines may be of single or multi-cylinder design and may operate on a two-stroke or four-stroke cycle. Apart from smaller vehicles such as motor cycles, the multi-cylinder four-stroke engine is generally favoured in this country regardless of the type of fuel employed.

The four-stroke engine is so called because, during a single complete cycle of operation, the reciprocating piston makes a total of four strokes, during only one of which, is useful mechanical energy made available. The first stroke comprises an outward movement of the piston whereby a fresh charge of air, with or without fuel, is drawn into the cylinder. During the second stroke this charge is compressed by an inward movement of the piston following which the compressed gas is heated by ignition of fuel previously admixed with the air or introduced at an appropriate stage. The heated gas then forces the piston outwards during the third stroke which comprises the power stroke after which the piston moves inwards for the fourth stroke whereby the products of combustion are exhausted so as to enable the whole cycle to be repeated.

It is not so much the difference between the fuels employed which distinguishes " petrol " and " diesel " engines—the latter can, in fact, be operated with petrol as fuel—but rather the means employed for bringing about ignition of the fuel at the appropriate stage during the engine cycle.

In " petrol " engines, ignition is initiated by means of an electric spark whereas in " diesel " engines advantage is taken of the fact that when a gas is compressed the mechanical energy expended during compression is converted into heat which, if not rapidly dissipated, causes the temperature of the compressed gas to increase. The engine is so designed as to ensure that during the second stroke of the cycle the charge of air is compressed to such an extent that its final temperature is sufficient to cause ignition of fuel brought into contact with the compressed air. No external source of ignition is therefore required.

The " petrol " engine is thus more properly described as a " spark ignition " engine and the " diesel " engine as a " compression ignition " engine but for the sake of brevity the more usual designations will be employed henceforth.

The difference between the means of ignition employed in the two types of engine gives rise to a number of fundamental differences in the mode of operation of the engines, their thermal efficiency and the mechanical design of the engines and associated equipment. It is not the purpose of this paper to consider these differences in any detail but certain of the more important features which have an influence upon the particular subject under consideration must necessarily be mentioned.

In petrol engines of normal design, fuel is introduced into the intake air by means of a carburettor so that during the second stroke of the engine cycle a mixture of vaporized fuel and air is compressed. Because of this the degree of compression must be limited so as to obviate any possibility of the temperature rising sufficiently to cause pre-ignition of the fuel-air mixture. On the other hand, in diesel engines, air alone is compressed and fuel is only introduced at the stage when it is desired that combustion of fuel should take place. Hence the degree of compression is not limited by any need to avoid pre-ignition and, in fact, the limit is in the other direction in that the degree of compression must be sufficient to ensure that ignition of fuel injected into the air will take place.

Now it can be shown that the thermal efficiency of an engine is primarily a function of the expansion and hence the compression ratio employed although indefinite increase of the latter is not possible on account of mechanical considerations. However, in practice, the compression ratio of a petrol engine can seldom be raised much higher than 8 to 1 whereas diesel engines normally operate at compression ratios of some 16 to 1. It is largely for this reason that diesel engines have markedly superior thermal efficiency compared with petrol engines and as a consequence are considerably more economical in respect of fuel consumption for a given amount of work.

The carburation system of a petrol engine demands the use of a volatile fuel which needs also to be specially blended to avoid combustion difficulties in engines of high compression ratio, tetra-ethyl lead nowadays being universally employed as an anti-knock additive. It is no easy matter to design a carburettor so as to maintain a desired fuel-air ratio throughout the whole range of engine operating conditions and it is also difficult to ensure uniform distribution of fuel to the individual cylinders of a multi-cylinder engine.

By contrast, the fuel for diesel engines is not required to be unduly volatile nor is it necessary to incorporate additives to obviate the effects of high compression ratios. Uniformity of distribution of the fuel to individual cylinders is readily achieved by reason of the fact that the necessary fuel injection pump meters fuel independently to each cylinder. In order to achieve satisfactory combustion, however, fuel has to be introduced into the engine cylinder by means of special injectors which perforce have to operate under what can only be regarded as the distinctly unfavourable conditions prevailing within the combustion space of an engine cylinder. Both fuel pumps and injectors are precision instruments which need to be carefully adjusted and maintained in order to ensure correct engine performance.

Satisfactory combustion of petrol vapour in air can only be achieved within a limited range of mixture compositions there being both lower and upper limits of fuel concentration beyond which the rate of burning becomes too slow to meet the demands of engine operation. For this reason petrol engines can only be made to work within a limited range of fuel-air ratios and in order to control the power output it is necessary to alter both the amount of fuel and the amount of air supplied to the engine so as to maintain an approximately constant mixture strength. This is effected by throttling the air intake, the carburettor being designed to introduce the requisite amount of fuel in accordance with the air supplied to the engine. The lower limit of fuel concentration which it is possible to employ corresponds to about 85 per cent. of the amount of fuel required for complete combination with the oxygen present in the available air. It is, on the other hand, possible to operate a petrol engine with an air-fuel mixture containing considerably more than the chemically correct quantity of fuel and as already mentioned such over-rich mixtures are necessary in order to achieve optimum power output. It will be appreciated that in such cases complete combustion of the fuel is quite impossible and, as a result, the products of combustion contain a considerable proportion of carbon monoxide. With over-rich petrol-air mixtures, however, it is unusual for much, if any, free carbon to be produced so that incompleteness of combustion is not normally productive of a smoky exhaust. In practice it is often the case that petrol engine exhaust may contain both carbon monoxide and uncombined oxygen as a consequence of maldistribution of fuel between individual cylinders of an engine.

In the case of the diesel engine the combustion process does not depend upon formation of an homogeneous mixture of vaporized fuel and air. Instead, minute droplets of fuel become ignited in the presence of an excess of air and there is thus virtually no limit to the extent to which the ratio of fuel to air may be reduced. It is quite normal for a diesel engine to idle satisfactorily with a mixture strength corresponding to a fuel concentration no greater than 15 per cent. of that needed to consume the whole of the oxygen present in the available air.

On the other hand, the droplets of ignited fuel can only continue to burn within a diesel engine if an adequate supply of fresh air can be brought into contact with them during the very short period of time available. Achievement of this is largely a question of ensuring a correct fuel spray pattern from the injector nozzles and obtaining a suitable degree of air swirl by proper engine design, but even so it is not possible to consume more than about 85 per cent. of the available oxygen if difficulties from incomplete combustion of the fuel are to be avoided.

Thus, in contrast with petrol engines, diesel engines can be operated with mixture strengths ranging from extremely weak up to a limiting maximum value which roughly corresponds to the weakest mixture strength which can be employed in petrol engines. In a diesel engine working within its rated capacity an excess of oxygen is always present during combustion and no more than a trace of carbon monoxide can be detected in the exhaust from such engines even though a haze of smoke may be formed.

Absence of any lower limit of mixture strength enables output control with a diesel engine to be effected solely by variation of the amount of fuel injected, the air intake being allowed to remain sensibly unaltered. When lightly loaded, therefore, diesel engines are operated on very weak mixtures and the exhaust gases are not only free from products of incomplete combustion but are also considerably diluted with excess air. The volume of exhaust gas, however, is greater than from an equivalent lightly loaded petrol engine in which the air intake must be throttled and it is necessary to take account of this when making comparisons between analyses of exhausts from engines of different types.

If the fuel delivery be increased beyond the normal upper limit, combustion in a diesel engine rapidly becomes seriously incomplete with resultant formation of large quantities of soot together with appreciable amounts of carbon monoxide. Under such conditions it is possible to obtain some increase in power output but only at the expense of a considerable increase in specific fuel consumption due to inefficiency of combustion.

It is thus most undesirable to operate

a diesel engine with an over-rich mixture strength and any attempt to do so results in the production of visibly objectionable exhaust. This behaviour, however, provides in effect, an automatic indication of the existence of incomplete combustion whereas a petrol engine exhaust may well become a quite unsuspected source of highly toxic compounds on account of the fact that incompleteness of combustion is not accompanied by any visible change in the appearance of the exhaust.

Combustion Control in Petrol Engines

The majority of operators, both of public service and goods vehicles, are concerned to keep their fuel costs at a minimum, and with the present high rate of taxation there is a marked incentive to ensure that engines and accessories are maintained in a manner such that fuel is not wastefully used. Incomplete combustion will therefore be avoided so far as is possible. The private motorist is also anxious to save fuel though his facilities for keeping his engine up to the required standard are not, perhaps, equal to those of the large fleet operator. There is, of course, a minority amongst both private and commercial owners who neglect their vehicles or, alternatively, are concerned only with obtaining maximum power output regardless of fuel costs or the eventual cost of premature engine overhaul or renewal. It is these vehicles, whether petrol or diesel type, which are responsible for an avoidable pollution of the atmosphere; they have, moreover, been the cause of much adverse criticism of the diesel engine, despite the fact that it is the more efficient power unit and if maintained and operated in a proper manner, is reducing rather than increasing the amount of pollution attributable to motor vehicles as a whole.

Vehicle manufacturers are as concerned as anyone else in ensuring that their engines should develop the rated output with the minimum consumption of fuel; fuel economy is, in fact, often stressed as a selling point. Customers are therefore advised as to the settings which should be adopted for the carburettor or fuel injection pump, and in normal circumstances the vehicles as delivered incorporate these recommended settings. The first steps towards achieving an efficient utilization of the fuel and thereby avoiding the emission of objectionable exhaust products, are to ensure that the settings are not interfered with and that carburettors or fuel injection pumps are maintained in a manner such that engine performance does not deteriorate. It is a wise precaution, and one that is followed by the majority of operators of diesel-engined public service vehicles, to derate engines so that power output is some 5-10 per cent. below the rated output. This is done by employing a correspondingly lower setting of the fuel injection pump than that recommended by the engine manufacturer, and provides a safeguard against variations in adjustment which may occur within periods of regular inspection and maintenance. A further advantage is that the life of engines between overhauls is increased. Derating is not peculiar to diesel engines but was also adopted by the former London General Omnibus Co. during the time that its fleet consisted entirely of petrol engined vehicles. As a result the proportion of carbon monoxide in the exhaust gases was much lower than is usual with petrol engines; at the same time a very substantial saving in petrol consumption was achieved.

A few words about the revision and standardization of carburettor settings introduced by the L.G.O. Co. over 30 years ago may not be inappropriate in that the methods employed are not without relevance today for operators of petrol-engined fleets. Moreover it is recognized, more so in the U.S.A., perhaps, than in this country, that the exhaust emission from petrol vehicles makes a very substantial contribution to atmospheric pollution; for example, the notorious eye-irritating " smog " of Los Angeles is largely due to the great number of private motor cars operated in that area.

The basis upon which the L.G.O. Co. standardized its carburettor settings was the composition of the exhaust gases. Carburettor settings, appropriate to the various types of engines in the fleet, were chosen so that the requisite vehicle performance could be obtained with an exhaust gas emission containing no more than $2\frac{1}{2}$ to 3 per cent. of carbon monoxide at full throttle; the idling setting was also appreciably weaker than was hitherto customary, permitting a maximum of only 1 per cent. carbon monoxide in the exhaust gases. These standardized settings were " registered " by exhaust gas analysis which was then used as a means both for ensuring that the settings were maintained and for diagnosing engine defects. The settings were made mandatory for all garages and no variations or unauthorised interference were tolerated. The carburettor jets were produced to the correct size, as determined by a standard flowmeter, in the Company's Laboratory and were checked at regular intervals on similar instruments, installed at each garage at which carburettor maintenance was carried out. Any jets found to be incorrect either as a result of being choked (rendering them too small) or becoming enlarged (as a consequence of too vigorous cleaning) were rejected and replaced by calibrated jets. Steps were also taken in co-operation with the supplier to standardize various other components of the carburettor. An overall check was maintained by taking samples of the exhaust gases from service vehicles run on the road under specified conditions. As a result of accumulated experience it was possible to interpret the results of these analyses and to list the various defects of the engine and accessories which might be leading to unsatisfactory combustion as revealed by departures from the " standard " exhaust gas analysis associated with the standardized setting. A detailed account of this method of controlling combustion in petrol engines was given in the February and March, 1935 issues of *Bus and Coach*.

Carburettor jets and other components of the carburettor assembly are not the only factors which influence combustion in a petrol engine. It is also necessary to ensure that the sparking plugs are regularly inspected and cleaned and the gap between the electrodes correctly adjusted; the adjustment depends upon whether the ignition system is of the magneto or coil type and varies also according to the compression ratio of the engine. Here again the engine manufacturer's recommendation should be followed. Dirty sparking plugs will lead to misfiring, and in addition to serious loss of engine power, both unburnt fuel and visible fumes are likely to be emitted from the exhaust outlet. Contact breaker points out of adjustment, with either magneto or coil ignition systems, will also lead to misfiring.

Accumulation of dirt in the air filter is another possible cause of emission of objectionable exhaust fumes due to the fact that the intake air supply is restricted thus producing an over-rich fuel-air mixture. Air filters should therefore be regularly inspected and cleaned. Worn cylinders and worn or otherwise defective pistons and rings will result in the emission of white or blue smoke arising from excessive consumption of lubricating oil. This condition can only be remedied by an engine overhaul, though a temporary alleviation may sometimes be effected by fitting new compression and scraper rings. There is, of course, a class of engine, namely, the small two-stroke as used in motor cycles and miniature cars, which depends for its lubrication on the use of a lubricating oil-petrol mixture, the lubricating oil in requisite proportion being deliberately introduced into the fuel tank. Such engines even when in first-class mechanical condition inevitably produce a smoky exhaust.

Combustion Control in Diesel Engines

The measures employed for controlling combustion in petrol engines, involving a rigid standardization of equipment and settings, together with a system of planned inspection and maintenance, are in principle equally applicable to diesel engines. Exhaust gas analysis is also of value and in the early days of diesel engines, before the development of a machine for testing and calibrating fuel injection pumps, it was the L.G.O. Co.'s practice, as the last stage in the course of vehicle overhaul, to set the pumps by reference to results obtained from analysis of samples of the exhaust gases. The composition of the exhaust gases corresponding to the standard setting for a particular type of engine had of course been previously determined and all that was necessary was to adjust the rack of the pump by a method of trial and error until the desired fuel—air mixture was obtained. For this purpose the vehicle was run on a test track at the requisite load and speed, exhaust gas samples being taken while the vehicle was in motion. When the correct adjustment had been obtained the pump was sealed to prevent unauthorized interference with the setting.

Nowadays, the correct setting of fuel injection pumps is achieved by means of a Hartridge type Fuel Pump Testing Machine the pumps again being sealed after testing. Garages are also provided with fuel pump testing machines, thus enabling the pumps to be checked and re-adjusted (after removal from the vehicle) at intervals of 22,500 miles. The adjustment permitted at garages is strictly limited and is confined to a minor re-setting of the rack, involving all six of the individual pump elements. If more than the permitted adjustment is required or if the variation in output between the individual elements is outside the prescribed limits, the pump must be returned to the Overhaul Works.

Precautions to ensure that the fuel injection pumps are correctly set and remain so within the inspection period are essential, but will not ensure freedom from exhaust smoke unless the injectors also receive expert attention. The injector maintenance period has considerably lengthened since the diesel engine first came into common use and some operators claim, with apparent justification, that if properly adjusted in the first instance, injectors will operate satisfactorily for 40,000 miles or more. In London Transport, injectors are at present cleaned and adjusted at 15,000 miles intervals, though investigations regarding the feasibility of extending this period have been carried out during the past three years and are still in progress. Maintenance procedure differs according to the make of the injector and complete dismantling and reassembly is only undertaken at the Overhaul Works. At garages, the injectors are partly dismantled and the needles are cleaned with a brass wire brush or with metal polish according to condition. Nozzle holes are carefully cleaned using a special " D "-shaped needle, the nozzle body being then washed out with a special fuel-pump test fluid. The unit is then reassembled and tested, firstly to ensure that the needle is not sticking. If it is, and the defect is not rectified after further cleaning, the complete injector is returned to the Overhaul Works. Otherwise, further tests are applied with the object of setting the injector release pressure, seeing that the spray is of the correct pattern, and confirming that leakage at the nozzle tip and between the needle and guide are within the very close tolerances laid down.

An important feature of the checking and re-adjustment of fuel injection pumps at garages is the allocation of one trained individual to this class of work. With the exception of a Fuel Economy Inspector (whose duties will be briefly referred to later on), no one else is allowed to break the seal on a pump and it is re-sealed after being tested. The same individual at garages is responsible for the cleaning and testing of injectors. Much of the success in maintaining the standard settings and in ensuring that the injectors are in serviceable condition is attributable to confining the work to one individual, a practice which was also followed in the days of the petrol engine when standardization of carburettor settings was adopted.

An independent check on combustion efficiency in diesel engines in London Transport's fleet is effected through the medium of a small group of Fuel Economy Inspectors who are under the control of the Research Department. These Inspectors are responsible for checking the fuel pump testing machines installed at both garages and Overhaul Works, to ensure that they are in proper condition and are consistent amongst themselves. For this purpose the Inspectors are provided with single cylinder fuel injection pumps used in conjunction with a carefully calibrated injector, which is itself standardized against a master injector held by the Laboratory. The Inspectors are also responsible for testing and re-standardizing as may be necessary, the special hand-pumps and pressure gauges provided for setting injectors to the correct release pressure and for carrying out the prescribed leakage tests. Garage records of tests on both fuel pumps and injectors are reviewed and any inconsistencies noted or difficulties encountered are taken up with the Fuel Pump Section at the Overhaul Works. The Inspectors are also equipped with small portable gas analysis apparatus suitable for determination of the proportion of carbon dioxide in exhaust gases and samples are taken at random from a number of service vehicles each week. By this means a kind of " quality control " on fuel injection pump settings is maintained. Moreover any variations from standard, as revealed by too high or too low a proportion of carbon dioxide in the exhaust gases of vehicles sampled, are at once reported to the garage concerned. Amongst their various other duties, the Inspectors spend a proportion of their time on the road and report by telephone on any vehicle observed to be emitting objectionable exhaust smoke. At three monthly intervals, a special survey of service vehicles is carried out, the Inspectors being reinforced on such occasions by an equal number of individuals drawn from the Engineering Department.

A detailed account of the system of maintenance of engines, fuel pumps, injectors and other accessories adopted by London Transport for its diesel-engined fleet of buses and coaches was given by one of the authors in a paper entitled " The Maintenance of Road Transport Engines with particular reference to smoke emission " read before the Diesel Engineers & Users' Association in March, 1956.

It will of course be appreciated that the various measures described in the foregoing can only be carried out by operators of comparatively large fleets of vehicles. The small fleet owner could not economically adopt such a procedure. Manufacturers of both engines and fuel injection equipment do, however, provide servicing facilities and the small operator would be well advised to take advantage of these aids to efficient maintenance.

Exhaust Smoke from Diesel Engines

As has been explained throughout the paper, emission of exhaust smoke from diesel engines can be kept to a minimum and acceptably low level by ensuring that the setting of the fuel injection pump is not in excess of that recommended by the engine manufacturer and by seeing that both fuel pump and injectors are properly maintained.

Black exhaust smoke is however inevitable if maintenance is neglected or, setting aside all questions of maintenance, if the fuel pump is set so that the power obtained from the engine is in excess of its rated output. This condition can only arise by deliberate action and assuming that it is not with the connivance of the operator the only remedy is to forbid any interference with the setting of the pump either by drivers or other staff unless authorized. Sealing the pump after calibration provides a partial safeguard and in London Transport there has never been an instance in which the seal has been deliberately broken. It does not however prevent a driver from altering the setting of the pump if he feels disposed to do so. The obvious corollary is that the engine fitted to the vehicle should have a power output such that it is capable of giving the desired performance when the fuel pump is set in accordance with the manufacturer's recommendation.

Another source of black smoke is an improper use of the excess fuel device fitted to certain engines as an aid to starting from cold. A device of this nature is not normally fitted to public service vehicles and the vehicles concerned are of the goods carrying class. The remedy is to instruct drivers that the device must not be used as a means for obtaining extra power from the engine; steps must also be taken to see that the instruction is obeyed. It may be added that engine manufacturers are now able to supply an extra fuel device which cannot be operated from the driver's cab.

Black smoke may also arise if the intake air filter is allowed to become choked or if the fuel pump governor is out of adjustment or is defective. As with the petrol engine, exhaust smoke, grey or white rather than black, will be emitted if the engine is in poor condition due to worn cylinders and/or defective piston assembly. All these sources of trouble can be avoided by proper attention to maintenance.

In conclusion mention should perhaps be made of the various devices which have been suggested, notably in the United States, for " cleaning up " the exhaust products from internal combustion engines. They aim at oxidizing combustible constituents in exhaust gases with the aid for example of a catalyst (as in the " Oxy-Catalyst " device) or of heat (as in the so called " after-burners " which are required to operate at a temperature of over 1,700 deg. F.). Both types of device are claimed to be applicable to petrol engines though only the former has been suggested for use in conjunction with a diesel engine. In neither case has the device been developed to a stage at which it is commercially available, though tests are in progress in the United States and at both the Fuel Research Station and the Safety in Mines Research Establishment in this country. Users view these devices with considerable scepticism. It is quite unlikely that they would be able to effect complete oxidation of hydrocarbons and other products of incomplete combustion in the exhaust gases. Moreover, their life would be expected to be short. Any device embodying a platinum catalyst is in addition bound to be very expensive. The authors are of the opinion that an operator who fails to maintain his engine and equipment in such a manner as to ensure proper utilization of the fuel would be unlikely to give the necessary frequent attention to still another piece of equipment which would not have been required but for his own neglect.

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(2) THE LAW AND ITS ENFORCEMENT

By

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Air pollution by road vehicles may well be likened to a cancerous growth, day by day, month by month, developing and growing with no known certain cure; Police are, however, looked to in assisting to arrest this growth.

It may be said that the growth commenced in 1769 when the Frenchman Guignot designed the first steam driven road vehicle; he was followed by Pierre Lavel, who in 1868 produced the first petrol driven engine. Who will deny that the question of danger and injury did not then arise and exercise the minds of these remarkable men in the construction and design of their engines; the unpleasantness they must have encountered from exhaust fumes when testing and running them becomes very real when one considers the advance in engine design since those days.

History records that the legislators of those times were alive to the dangers inherent in these engines by the emission of soot, sparks, smoke and fumes, and yet one cannot dismiss from the mind that the danger from speed, unreliable steering and braking were uppermost in the minds of the law makers of that day.

For the purpose of this paper the road steam engine will not be treated as of major importance in our modern system of road transport, although it cannot be entirely divorced from the internal combustion propelled vehicle. On looking back it is of interest to note that with the advent of mechanical road transport we had much legislation in connection with this subject in the form of The Highway Act, 1835, and The Locomotive Acts, 1861, 1865 and 1898, The Locomotive on Highway Act, 1896, The Highway and Locomotive Amendment Act, 1878, The Motor Car Act, 1896, The Motor Car Act, 1903, and the Construction and Use Order, 1904.

Section 12 of The Locomotive Act, 1865, enacts that " no locomotive shall be a public nuisance." One is tempted to wish for such clear-cut legislation in our present legal system. All these Acts and Orders played their part in ensuring that the makers at least were made to comply with certain safeguards as were then known.

With the ever changing times design was improving and the number of vehicles increasing daily. What was, up to the 1930's a matter of some importance, was now becoming a matter upon which all sections of the public were showing intense interest, if not concern. The internal combustion engine had developed on a twin basis, the petrol engine on the one hand, the diesel on the other, both operating on the same principle but with a different method of combustion and both emitting fumes by way of exhaust gases.

Consider the petrol engine—the excessive wear of the cylinder bore, pistons, piston rings and grooves resulted in oil intended only as a medium of lubrication becoming mixed in large quantities with the explosive mixture, resulting in excessive exhaust smoke. One has only to ride in a vehicle with a badly worn engine and experience the unpleasantness of the fumes, coupled with loss of power, to appreciate that it is not possible for a driver of such a vehicle to plead ignorance of the true position.

Although at this stage it is not suggested that this is a serious problem, the rapid expansion in the use of the two stroke " petroil " engine now becoming so popular in scooters and three-wheeled lightweight vehicles, must add to this problem. In these engines a mixture of petrol and oil to a ratio of between 16 and 24 to 1 is injected into the engine via the carburettor. Thus it will be seen that should more oil than the correct amount be added to the petrol, excessive smoke will result.

In the case of diesel driven vehicles, the causes of excessive smoke may arise from carbonization of the injector, causing an irregular and uneven distribution of fuel, wrongly calibrated fuel pump, causing too much fuel to be injected, or injected at the wrong moment, or a combination of both, and/or incorrect valve timing; timing early or late will result in excessive smoke.

As to the law, how has its enforcement advanced in relation to the expansion of road traffic? Sections 3, 30 and 111 of the Road Traffic Act, 1930, empowered the Minister of Transport to make regulations for regulating the design and construction of road vehicles and their use upon highways and impose penalties for failure to comply with such regulations.

Construction and Use Regulations have been made from time to time and have been amended as seen fit in the light of altering circumstances, the last of these, The Construction and Use (Amendment) Regulations, 1957, coming into operation as recently as April 1st, 1957.

It is opportune owing to this recent change in the law to compare the regulations applicable to our subject as applied before April 1st, 1957, and from which our experience is in the main derived; and as operative from April 1st, 1957, giving the position as it is today.

Firstly, let us consider the Construction and Use Regulations, 1955, Regulations 21, 22 and 79.

Regulation 21—" Every motor vehicle shall be so constructed that no avoidable smoke or visible vapour is emitted therefrom."

Regulation 22—" Every motor vehicle using solid fuel shall be fitted with an efficient appliance for the purpose of preventing the emission of sparks or grit and also with a tray or shield to prevent ashes or cinders from falling on to the road."

Regulation 79—" Every Motor Vehicle shall be maintained in such a condition, and shall be so driven and used on a road that there shall not be emitted therefrom any smoke, visible vapour, grit, sparks, ashes, cinders or any substance, the emission of which could be prevented or avoided by the taking of any reasonable steps, or the exercise of reasonable care, or the emission of which might cause damage to other persons, or property, or endanger the safety of any other users of the road in consequence of any harmful content therein."

Regulations 21 and 22 do not present any difficulty as these are matters taken into consideration by the makers in the construction of the vehicle and as such are their responsibility and are adhered to by them.

Regulation 79, however, created certain difficulties with regard to enforcement. In simple terms proof is required—" That the vehicle was emitting smoke, visible vapour, grit, sparks, ashes, cinders or oily substance which could have been prevented by the exercise of reasonable care and maintenance and that the vehicle was emitting smoke, visible vapour, grit, sparks, ashes, cinders or oily substance which might cause damage to other persons or property or endanger the safety of road users in consequence of harmful content."

Dealing strictly with air pollution and omitting from this paper what may be termed the parts applicable to steam driven vehicles, we are left with smoke, visible vapour and oil substance. What must the Police prove?

(i) " That there might be damage to other persons or property, or that the safety of some other road user was endangered by the harmful content of the smoke, or

(ii) That the offence of the vehicle emitting smoke could have been prevented or avoided by the exercise of reasonable care and maintenance."

It will now be appreciated what difficulties arose in the enforcement of such Regulations.

So far as paragraph (i) is concerned, proof required is of what might have occurred, damage to persons or property, or that road users were endangered by the harmful content of the smoke. Damage to persons or property might be said to be imminent by such an amount of smoke as to make visibility to a passing or overtaking motorist difficult and hazardous. There may be evidence of damage by the emission of an oily substance, but how to gauge and assess and put into words the volume of smoke emitted was the real problem. What might have been evidence to convince one court might not convince another. To prove that road users were endangered by the harmful content of the smoke presumably would require specialized medical evidence, whereas in the case of damage which might have occurred, the only satisfactory method was to prove actual damage.

It therefore follows that such offences as were prosecuted by Police fall in the main in category (ii), i.e., those in which smoke could have been avoided by the exercise of reasonable care and maintenance. However, proof of the absence of reasonable care and maintenance frequently requires evidence of a highly technical nature which only a relatively small number of Constables were qualified to give, coupled with the fact that if challenged the only positive evidence could be obtained by the internal examination of the engine which Police had no power to carry out.

In fact, " lack of maintenance " was in many instances challenged by the calling of expert witnesses to prove that there was nothing wrong with the engine and that regular overhaul and checks of the engine had been carried out. Therefore, no offence was committed. In these cases the summonses were dismissed.

In spite of this, it is quite evident from enquiries I have made that Police were giving this matter their attention and offenders were being reported. Many others, where the offence was of a minor nature, were either being cautioned or verbally warned on the spot by the police officer concerned.

In order to see this picture in its true perspective I consider it appropriate to reproduce three relevant extracts.

" *Hansard 2nd March,* 1954. *Parliamentary Report. House of Lords. Diesel Engines. Exhaust Gases.* In this debate Lord Lucas of Chilworth put down a Motion asking Her Majesty's Government whether they would take the necessary steps to enforce the law relating to the emission of exhaust gases from diesel engines fitted to road vehicles, and so prevent the injurious effects upon the health of the people, and in addition make a contribution to road safety.

" Lord Teynham and Lord Lucas contributed to the debate which to a very large extent centred on the reasons, with opinions and contradictions, for the emission of smoke from these vehicles.

" Lord Loyd in reply said: ' My Lords, I had hoped that this question would clear away a certain amount of fog, but having listened to the three noble Lords, I am not sure that the fog is not becoming thicker than ever.'

" Later in the debate in referring to a speech made by Lord Chilworth Lord Loyd is reported: ' The noble Lord, as usual, has a touching confidence in the Police and in my present position I always like to see that. He thinks that this matter can be put right quite easily by Police. He says and indeed he is right, that two Regulations govern this subject, and he quoted them *in extenso*, to your Lordships. I do not think I need repeat them again beyond saying that first of all they are not easy Regulations to enforce,' etc., etc.

" He did, however, in conclusion promise to bring the debate to the notice of Chief Constables, also to consider the Regulations to see whether they fulfil the purposes for which they were originally framed."

The following extract from *The Commercial Motor* dated March 12th, 1954, entitled " Lost in a Fog " is of note.

" It seems likely that as a result of the complaints in the House of Lords last week, the Police will pay still greater attention to the emission of excessive smoke by oil-engined vehicles. The Home Secretary is to refer Chief Constables to the debate and to the potential dangers arising out of the discharge of clouds of smoke. The present regulations are to be re-examined to determine whether they are adequate.

" The dangers inherent in the emission of exhaust gases from oil-engined vehicles were grossly exaggerated, although there can be no doubt that thick black smoke is a great nuisance to other road users by obscuring vision. It is also extremely wasteful, for an engine with a thick exhaust is inefficient.

" Lord Lucas rightly said that the oil engine was a masterpiece of British engineering and that manufacturers took meticulous care to ensure that negligible quantities of smoke were discharged. He was also correct in stating that the standard of maintenance on the part of large operators was high.

" He was, however, on less certain ground when he ascribed black exhaust partly to tampering with injection pumps by drivers. This is extremely unlikely. Pumps are sealed and if a seal is broken the guarantee on the engine is nullified. Moreover, special spanners are required to alter a pump setting and these are unlikely to be held by drivers.

" His suggestion that the motor industry should conduct close research into the incidence of smoke and the prevention of tampering with injection pumps is unnecessary. The problem is one of educating small operators and maintenance staffs in proper upkeep and here again manufacturers are doing their best by running special training schools for customers' employees.

" Lord Teynham, who usually speaks with authority on matters of road transport, was also wide of the mark in suggesting that vertical exhaust pipes might be used, so that the gases could be carried away from the vehicle. This solution of the problem might be easy if there were no double-deck buses. During the war, when a gas-producer bus was left in a bus station with its engine running, passengers on the upper deck of a neighbouring vehicle were overcome by the fumes and had to be removed to hospital.

" Lord Lucas was also befogged when he claimed that the pollution of the atmosphere by oil engines in road vehicles was injurious to public health. If breathed close to their source, as on the upper deck of a bus with a vertical exhaust pipe, fumes are obviously dangerous, but under normal conditions they are not. The Interim Report of the Committee on Air Pollution, published last December, stated that of the 5·3 m. tons of sulphur dioxide discharged into the air in a year, only 20,000-40,000 tons came from stationary and vehicle oil engines.

" Even the petrol engine, the exhaust of which may contain a high proportion of carbon monoxide, does not make a serious contribution to pollution, for it produces annually only 4 m. tons of the 24 m. tons of that gas emitted into the air. The sulphur dioxide content of a petrol engine exhaust is negligible.

"An independent scientific investigation into air pollution in greater London has produced even more striking evidence in favour of the oil engine. It has been estimated that 34·7 m. tons of coal and other fuels are consumed in the Metropolis each year. These yield 350,000 tons of smoke, 100,000 tons of grit, 880,000 tons of sulphur dioxide, 3·3 m. tons of carbon monoxide and 50,000 tons of hydrochloric acid and other fumes.

" By comparison, 990,000 tons of petrol and 190,000 tons of oil fuel are estimated to be used annually be road vehicles in Greater London. Assuming that all the oilers were working at normal efficiency, they would emit 800 tons of smoke, 2,700 tons of sulphur dioxide, 6,800 tons of carbon monoxide and 7,200 tons of hydrochloric acid, etc.

" If all were neglected, the figures would become: smoke 4,700 tons, sulphur dioxide 2,700 tons, carbon monoxide 12,300 tons and hydrochloric acid etc., 10,300 tons. Even so, the proportion of pollutants issued by them would be minute compared with the amount resulting from burning coal and other fuel.

" Lord Lucas declared that if the use of oil engines greatly extended, what was already a nuisance would become a menace. Figures can again be quoted to disprove that statement.

" If all the motor vehicles in Greater London had oil engines and were operating at normal efficiency they would emit, in a year, 5,000 tons of smoke, 20,000 tons of sulphur dioxide, 45,000 tons of carbon monoxide and 48,000 tons of hydrochloric acid etc. If they were all neglected, the emission of smoke would rise to 24,000 tons, sulphur dioxide would remain at 20,000 tons, carbon monoxide would increase to 80,000 tons and hydrochloric acid to 67,000 tons.

" Even under those extremely unlikely conditions the amount of pollution by oil-engined vehicles would still be negligible in comparison with that caused by the burning of coal and other fuels by householders and industrial consumers.

" Lord Lucas was wise enough not to claim that the pollution of the atmosphere by oil engines was a direct contributory cause of lung cancer. Large operators and manufacturers of oil-engined vehicles are, however, becoming apprehensive lest, as a result of research by tobacco interests, the recent alarm about the dangerous effects of smoking is proved to be false. Busybodies might then consider it necessary to find a new scapegoat for cancer and the oil engine might become their victim. This is a possibility against which the industry must be on its guard."

I would also like to refer to a paper by Mr. E. T. Wilkins, M.SC., PH.D., M.R.S.H., Principal Scientific Officer, Fuel Research Station, presented to a seasonal meeting of the Royal Society of Health held in London on June 13th, 1956, whose introduction states:

" Whereas the discharge of the main pollutants, grit, smoke and sulphur dioxide, amount to about 1, 2 and 5 million tons a year respectively, that of carbon monoxide totals about 24 million tons a year. This latter amount is composed of about 10 million tons from industrial chimneys, 10 million tons from domestic appliances and 4 million tons from the exhausts of motor vehicles, but owing to the differences in the conditions under which carbon monoxide is discharged from the chimneys and from motor vehicles, the relative quantities of these emissions afford no criteria of their contribution to the ground level pollution of the atmosphere by carbon monoxide. Domestic and industrial chimneys produce large volumes of flue gases which are discharged at considerable height and contain relatively low concentrations of carbon monoxide (about 0·01 to 0·5 per cent.). The exhausts from motor-cars average about 4 per cent. of carbon monoxide and are discharged close to the ground.

" In spite of the well known toxicity of carbon monoxide, little attention seems to have been paid in this country to the possibility that excessive concentration may occur in the air of streets. A few data were published about twenty-four years ago; since that time the annual consumption of petrol has risen from little more than 3 million tons to nearly 6 million tons in 1954, and still seems to be rising. A conclusion from some of the results in this paper is that most of the carbon monoxide occurring near ground level comes from petrol driven motor vehicles. There is, therefore, an obvious need for keeping the problem of air pollution by carbon monoxide under review."

A number of tables are then given showing measurements of carbon monoxide per million parts of air by volume (PPM) showing in London streets in 1931-1932 an average of 34 parts CO.PPM. rising to 100 CO.PPM. during traffic blocks. Investigation in other large cities shows concentration as high as 230 CO.PPM. Berlin 1930-1932, 460 CO.PPM. New York 1923, 160 CO.PPM. Los Angeles 1955.

As will be seen, these tables were compiled, with the exception of Los Angeles, on data of twenty-five years or more ago.

Following the Parliamentary Debate already referred to, the enforcement of the Regulations then in being was brought to the notice of Chief Officers of Police and, as promised, the Construction and Use Regulations were amended and have since been amended again.

Let us now turn to Regulation 79, Construction and Use Regulations, 1955, as amended by the Construction and Use (Amendment) Regulations, 1957, which came into force on April 1st, 1957, under which we are now working. (Regulations 21 and 22 were not affected). Regulation 79 now reads: " No person shall use or cause or permit to be used on a road any motor vehicle from which any visible vapour, grit, sparks, ashes, cinders or oily substance is emitted, if the emission therefrom causes, or is likely to cause, any damage to any property or injury to any person, who is actually at the time or who reasonably may be expected on the road, or is likely to cause danger to any person as aforesaid."

It will be seen at once that all reference to maintenance and reasonable care has been omitted. The legislators have apparently based their hopes of successful prosecutions in requiring Police to prove injury or damage only or the likelihood of such injury or damage.

The offence under the amended Regulation can be set out simply as follows: " The emission of smoke . . . likely to cause damage to property or injury to persons, or likely to cause danger to a person."

It is obvious for reasons already given in relation to " damage " and " injury " that in the main, prosecutions will in future be dealt with under the part relating to " likely to cause danger to any person." Whether the Regulation as amended is likely to result in more prosecutions is doubtful as Police evidence in relation to the possible danger to a person will almost certainly be in respect of the interference with the view of other road users. It therefore seems that the emission of smoke under the amended Regulations will have to be considerable, having regard to the absence of any simple method of measuring smoke density to ensure successful prosecutions.

Now what of the policeman with much else to do? It must be admitted that figures regarding action by way of prosecution are low, due no doubt in some measure to the difficulties already referred to. My Association is, however, aware of the National Smoke Abatement Society's anxiety that Police and Local Authorities should be more active in dealing with exhaust fumes, more particularly those from diesel engined vehicles. It is hoped that the new Regulation operating from April 1st, 1957, will prove easier to enforce than is at present envisaged. Every Force up and down the country is alive to this problem and is trying to effect an improvement mainly by verbal warning and advice. It is small wonder, however, that the number of cases in which drivers are in fact reported and summoned for offences in connection with exhaust gases receive scant publicity in competition with the more sensational crimes which are so adequately reported by the Press, and I can only hope that the work of the National Smoke Abatement Society in this field will receive the publicity it deserves in the future.

Delegates will by now have appreciated the fact that in Hastings we do not experience the nuisance attributed to the larger industrial areas; because of this I considered it important that the views of other Chief Officers of Police should be obtained and it is my duty and pleasure to acknowledge here the assistance I have received from the Commissioners of the Metropolitan and City of London Police, the Chief Constables of Birmingham and Peterborough, and from overseas, the Commissioners of the Royal Canadian Mounted Police, the Victoria Police and New York City Police, U.S.A., and I am much indebted to these officers for their interesting and informative reports.

Comment from Abroad

The comments from abroad are of particular interest and I consider the following worthy of note.

In the City of New York, U.S.A., the problem of air pollution is considered to lie in the industrial field; there has in fact been little legislation dealing specifically with road vehicles.

Regulation 167, Smoking Vehicles, of the Traffic Regulations of the City of New York, however, touches on the problem and lays down that " No driver shall proceed whilst his vehicle is emitting dense or unnecessary quantities of smoke," whilst Regulation 81, Vehicle and Traffic Law, states that " No person shall operate upon a public highway a vehicle which emits unnecessary smoke or unnecessary offensive vapours."

Presumably Section 167 is framed to deal with vehicles proceeding, whilst Regulation 81 would allow for stationary vehicles.

The Regulations were filed with the City Clerk on November 10th, 1955.

In proving the offence the police officer would testify as to the length, height and width of the smoke stream and to its colour and general density. There is no requirement that the smoke itself be produced as evidence. In effect, the case resolves itself into one of fact and credibility for the Court to decide. The City's case law is barren of any appeals from these convictions.

It is of particular interest to know that there were only 146 violations of this Section reported in 1956 in the entire City of New York.

In Ottawa the only legislation is that contained in byelaws of the City and reads: " No person shall discharge into the open-air the exhaust of any steam engine, stationary internal combustion engine, motor vehicle or motor cycle, except through a muffler or other device which effectually prevents loud or explosive noises, and all motor vehicles equipped with diesel engines shall have exhaust pipes extending perpendicular to the height of the roof of the said motor vehicle. This section shall not apply to diesel powered taxicabs or diesel buses."

It is reported that transport trucks operated by diesel motors carry perpendicular exhaust pipes extending above the cab of the vehicle.

From the above it will be seen that providing the vehicle is fitted with an efficient silencer, the problem of smoke volume does not arise and Police action cannot be taken. Small wonder that Ottawa Police report they have no problem.

Further enquiries of the position at Toronto, Vancouver and Montreal reveal that with the exception of Montreal, no provision is made for covering air pollution by motor vehicles.

In Montreal the problem is dealt with under a byelaw which reads: " No vehicle shall emit a dense smoke." Again no problem and no prosecutions are reported. Perhaps here the legislation is so easily understood that it is complied with.

One is inclined to speculate on the position of passengers on a double deck omnibus in a traffic jam with vehicles on either side fitted with perpendicular exhausts extending above the cab of the vehicle belching diesel fumes, recalling especially the pertinent remarks in the article " Lost in a Fog " already quoted.

In Melbourne, Australia, Legislation is provided in the following: " Where a motor car on any highway emits, except from some temporary or accidental cause, smoke or visible vapour or any offensive noise or smell of such a quantity or extent as to be an annoyance or danger to the public, the owner and the driver of such car shall each be guilty of an offence against this Act."

Some successful prosecutions have been undertaken, but the general view appears to be that the cause of such offences is faulty maintenance and alteration of fuel stops and opening adjustment jets. Here Police have power to affix a label to any offending vehicle requiring repair, adjustment, or reconditioning, and to serve notice prohibiting the use of such motor-car, or trailer, on and after a date specified in such notice unless and until such repair has been carried out and the vehicle has been presented for a further inspection and a certificate issued to this effect.

It is stated that the members of the Police Force attend a Road Safety Vehicle Testing School where they are instructed in the principles and functions of diesel engines and in particular the operation of a correctly adjusted fuel pump stop and position of the manufacturer's seal. It is also stated that in the opinion of those responsible for enforcing this legislation, it is sufficient to deal with the problem.

Whether or not a police officer should be required to act as an expert mechanic and examiner of vehicles is not within the scope of this paper, but I venture to say that whilst at first sight this may appear to offer a solution, the implementation of such an Act or Regulation in this country would be impracticable under present conditions.

Finally, I would like to express on behalf of the Association of Chief Police Officers of England and Wales our sincere appreciation and thanks to the National Smoke Abatement Society for the opportunity afforded us in expressing our views on pollution of the air by road vehicles and enforcement of the law on this subject. With the advent of the turbine, increasing speed and size, what the future holds in store I will not hazard a guess. In the nuclear age must one now look ahead to the days of atomically propelled road vehicles? When this day comes the lot of the policeman, armed with a " Geiger counter," may be a happier one.

Discussion

Dr. J. L. Burn (Salford) said that as happens in other fields of public health work, informal actions sometimes produced better results than legal action. Contact could be made by means of the registration number or name of the owner of the vehicle. He had been surprised at the understanding way in which these representations had been received; on several occasions the owners had admitted that the engine was not mechanically efficient and had promised immediate remedy. It seemed a coincidence that in so many cases the vehicle had been " just on its way to the repairers for overhaul! " Whilst he would not hesitate to recommend formal measures in flagrant cases or repeated offences, informal action had produced real improvement in abatement of air pollution from vehicles, and also in road safety, and doubtless in economy.

V. W. Dale (British Electrical Development Association) said that he joined issue with the authors of the first paper in respect of the reference to electrically propelled vehicles. It was not, he said, a question of the *volume* of the pollution but the *level* at which it was delivered.

In any case, the difference of opinion of " experts " on either side was bound to give the layman the impression of " bally-hoo ". For example, an authority in the Electricity Supply Industry, holding much greater responsibility than the authors in their particular sphere, recently wrote thus:—

> " Power stations are often singled out for special, though uninformed, criticism as being a major source of atmospheric pollution. Except in one or two isolated cases of extremely old and inefficient stations inherited by the Central Electricity Authority, the reverse is the case."
>
> " In addition to efficient combustion, all modern stations are equipped with the most up-to-date mechanical and/or electrostatic grit arrestors which have efficiencies of up to 99 per cent.—which means that practically all the grit is removed from the flue gases before they are discharged into the air. Not only are these gases clean, but they are dispersed at high level so that the concentration in the atmosphere is small. A series of extensive tests which are being carried out in different parts of the country show that power stations make no significant contribution to pollution of the surrounding atmosphere compared with the open grates in 14 million domestic dwellings."

Mr. Dale said it was all very well for the authors, representing the oil side, to give what might appear to be a biassed view in their paper, but he thought it was the responsibility of the Society to exercise a balanced judgment and give an authoritative statement on this issue.

He believed that an ounce of practice was worth a ton of theory and he challenged Mr. Styles to accompany him for half an hour between the Law Courts and Trafalgar Square mixing with the dense oil-engine traffic: he, for his part, would undertake to bring together a fleet of electric battery vehicles and trolleybuses and thus simulate conditions equivalent to the former test. At the conclusion of each part of the test they would submit to a medical test.

Mr. Dale said that being a temporary resident in Hastings he did not feel disposed to argue with the Chief Constable: nevertheless he commended to the London Transport Executive Mr. Archer-Burton's far-seeing peroration in which he modestly refused to hazard a guess at the revolution in Transport which was bound to happen as a result of the increasing speed and size of the turbine, to say nothing of which might be in store in the nuclear age which was already upon us.

J. W. Batey (Sheffield and District Clean Air Committee) drew attention to the authors' statements that (a) the fuel injection pump had a recommended setting which should not be interfered with; the " as received from the makers " condition would avoid the emission of objectionable exhaust fumes. A little further on they stated that (b) " It is a wise precaution and one followed by the majority of operators of diesel-engined public service vehicles to derate engines . . . This is done by employing a correspondingly lower setting of the fuel injection pump than that recommended by the engine manufacturer . . . "

The two statements were contradictory and he would like the point clarified by the authors.

Dr. F. G. Tomlins spoke as an independent general practitioner who valued the internal combustion engine, but whose duty was to try to help those dying of chronic bronchitis and lung cancer, for which conditions there was little effective treatment. He hoped the *Commercial Motor* would not consider him a busybody because he was concerned with possible causes of these diseases.

He noted that Messrs. Styles and Wilford admitted that air pollution from internal combustion engines could not be eliminated and that they sought to show merely how it could be minimized. He agreed that exhaust cleaning was unlikely to be practicable.

Although only the fuel supplier could remove sulphur from Derv, the onus lay on the operator to ensure that that was done. It was untrue to say that use of pure hydrocarbon fuel and perfect combustion would eliminate air pollution. There would still be oxides of nitrogen, composed of two main substances, nitric oxide (NO) a respiratory catalyst inhibitor and precursor of the other main component, nitrogen dioxide (NO_2), an acute bronchial and pharyngeal irritant, capable of causing acute bronchitis, and probably, after repeated slight exposure, chronic bronchitis. The diesel engine produced up to ten times as much of these substances as the petrol engine. American authorities [1] suggested a maximum permissible concentration for eight hours exposure of 5 p.p.m. calculated as NO_2, and Wilkins[2] had suggested that street concentrations might reach 1·5 p.p.m., but had not allowed for the much larger exhaust volume from Derv than from the equivalent amount of petrol, and for the high diesel to petrol vehicle ratio in city streets—Wilkins' figures, corrected for these factors, gave street concentrations of 6-8 p.p.m.[3, 4] Commins, Waller and Lawther[5] had attempted to refute those calculations by publishing measurements showing NO_2 values of 0-1·1 p.p.m. at the Bank in the City of London but they had measured NO_2 only and not NO. The greater part of the oxides of nitrogen from the diesel engine were produced as NO which was converted to NO_2 only slowly in the air, but possibly much more quickly in the lungs.

Toxicity from oxides from nitrogen was not reduced by good maintenance. Pattle *et al*[6] had shown that a diesel engine under load and in good condition produced an exhaust more toxic (because of more NO_2) than one with a worn injector, and also more irritant. Pattle had written " the fact that our least irritant fumes were obtained with a faulty injector demonstrates the fallacy of supposing that the requirements for mechanical perfection in an engine are identical with those for a medically harmless exhaust." In none of Pattle's experiments were the fumes black or smoky, hence diesel engine exhaust was toxic without black smoke.

While agreeing that internal combustion engines produced polycyclic hydrocarbons some of which were carcinogenic, Styles and Wilford stated that recent work had shown that the quantities produced by well maintained diesel engines were insignificant. No source was quoted, but it was presumably Commins, Waller and Lawther[7] whose work had been done on empty buses moving on a level garage floor. Output of total hydrocarbons increased with load; one must be sure that output of polycylic hydrocarbons from average buses in service did not increase with load before accepting garage figures as applicable to street conditions, where pollution might well be much worse.

One must remember that lung cancer was increasing and that the increase was due not only to tobacco smoking, but partly to atmospheric pollution. The increase among non-smokers was much greater in town than in country and Stocks and Campbell[8] suggested that 50 per cent. of the increase was due to tobacco and 37·5 per cent. to atmospheric pollution. Doll[9] had stated that " changes in mortality from lung cancer clearly cannot be attributed to changes in the amount of coal smoke in the atmosphere " —this source of pollution had been decreasing for the last fifty years as the proportion of smoke burnt efficiently, in electric power stations, etc., increased. The most likely large-scale widespread and increasing factor was the internal combustion engine. The carcinogens in internal combustion engine exhaust might include polycyclic hydrocarbons and partial oxidation products of hydrocarbons[10]. Unburnt oil fuel and cylinder lubricant were also present and were probably important as solvents and activators for carcinogens[10, 11], including the benzpyrene adsorbed on to coal soot particles where it was normally inactive biologically.

Thus the internal combustion engine, including the well maintained diesel, was toxic, certainly as a lung irritant causing bronchitis, and probably as a cause of lung cancer. From the health aspect what mattered was the amount of pollution inhaled. In country areas air pollution, being much diluted, was not very important and there the internal combustion engine was relatively unobjectionable. In towns, air pollution was very important, and there it was important to reduce the numbers of internal combustion engined vehicles as far as possible.

Certainly in urban passenger transport there was much scope for this reduction. First, to reduce use of and pollution from private vehicles, both cars and small two-stroke engined vehicles such as minicars and scooters, the very oily exhaust of which might be particularly dangerous, the public must be persuaded to use public transport. To do this, public transport must be attractive, cheap, and, most important, must not leave behind intending passengers. Experience in Great Britain, including London, suggested that these standards could not be achieved on busy routes by buses of any type. On a recent visit to continental cities using modern high capacity trams, Dr. Tomlins said he was impressed by the fact that even at peak hours he was never left behind, and suggested that such trams should be used in Britain.

Secondly, to reduce pollution from public vehicles, motor buses should be replaced by electric trams on busy routes and trolley buses on medium routes. Messrs. Styles and Wilford's statement that replacement of motor by electric vehicles would increase overall air pollution was highly misleading, since it ignored the site of the pollution. Wilkins[2] had stated that " the relative quantities of emissions afford no criteria of their contribution to ground level atmospheric pollution." Vehicle exhausts were discharged near to pedestrians and often in confined streets, whereas power stations effluents were discharged 300 feet above ground and were dispersed. Vehicle exhausts were also more toxic than power station effluents. Atomic power stations should produce no air pollution while with hydroelectric stations the question did not arise.

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G. C. Smith (C.P.H.I., Kingston-upon-Thames) in referring to the paper given by Messrs. Styles and Wilford, said that the public generally were to be thankful that London Transport Executive had adopted the policy of derating all engines. This, together with a high standard of maintenance, was a most important factor. As on rare occasions Mr. Smith had noticed London Transport vehicles emitting smoke, he asked whether there was any point in notifying the fact to the Executive.

Referring to the paper given by Mr. Archer-Burton, Mr. Smith said that like Dr. Burn, he had done much work of an informal character but the problem had become too great to be dealt with in that manner. Whilst the more reputable firms would co-operate, nothing could be done with those who refused to take any notice. Mr. Smith said that in his opinion the quoting of extracts from the *Commercial Motor* and from the paper by

Mr. Wilkins relating to the amount of pollution from road vehicles were useless. The important factor was the point at which such pollutants were discharged.

In spite of what had been said about the difficulties in enforcing Regulation 79, he still felt that the Beaver Committee were right in their assertion that at the time they made their report, there were adequate legal requirements for dealing with pollution from road vehicles. It appeared obvious that no serious attempt had been made to enforce the regulation.

Mr. Smith agreed with Mr. Archer-Burton that prosecutions in respect of badly maintained road vehicles did not make front page news in the national press but he did submit that such prosecutions would find their way into local papers. He had never seen a case reported, although he had noticed many cases that had been taken in respect of faulty brakes, steering, or drivers being drunk in charge. In these latter cases, medical evidence was produced in order to prove the cases. He felt that whilst police officers were trained to handle dogs or for special traffic control duties, and in the use of radar equipment to detect speed, no difficulty would be presented in training a small number of officers to deal with badly maintained diesel engines, alternatively, as in the case of medical experts, technical advisers could be retained or called in for the purpose.

Mr. Smith said that in his opinion atmospheric pollution of the character which was under discussion should be dealt with as a public health matter and that Public Health Authorities should be given powers to deal with it. He referred to a conversation he had had that morning with a man who had had an opportunity of observing the effect of the smokeless zone in Manchester. Whilst from observations from the higher windows of buildings the air was clear, it was hardly fit to breath at ground level. He asked what was the use of clearing the sky above if people could not walk the streets in safety.

D. Lister (County Health Inspector, Northumberland County Council), viewed with dismay the amendment to the Construction and Use Regulations and said the only prosecutions certain of success in future would be where the volume of smoke was such as to prejudice road safety. He was not hopeful about the suggestions of verbal warning and informal advice, in view of the irresponsible attitude of certain transport users, and gave as an instance the prevalence of serious overloading among goods vehicle operators, a practice which unfortunately was still financially attractive in spite of increased wear and tear. He referred to the lack of any objective method of measuring vehicle smoke density as a major difficulty, and suggested that some use might be made in this connection of the vehicle testing stations, to be set up under the new road traffic legislation.

On the question of petrol-lubricated two-strokes referred to in both papers, he complained of the lack of comparative data on the emission of pollutants from such engines, which though small and of low fuel consumption, were increasing in numbers at a fantastic rate.

Regarding catalysts, Mr. Lister thought that a reduction in cost might follow successful experiments recently announced with vanadium pentoxide, a by-product of the refining of uranium, but like the authors of the first paper he was somewhat sceptical about the ultimate benefit to be derived from such devices.

Councillor H. W. Barnes (Blackpool), said there was no doubt of the necessity for neutralizing the deadly gases from road vehicles. He remembered when motoring was a means to health, but there had been a complete reversal: motoring was now the quickest way to ill-health. People were riding continually in contaminated air. Beauty spots, as well as cities, were suffering. It was generally accepted by medical authorities that four hours fresh air each day was a condition for good health. Fresh air was now denied to thousands. It was disheartening to note the deterioration in that direction as against the improvement resulting from smoke abatement action. He was appalled by the fact that it was impossible to walk in suburban areas without being assailed by this deadly nuisance. He remained to be convinced that it was not a serious factor to causes of lung cancer.

Councillor Barnes said that he felt that the human element in the educating of motorist to sound mechanics was no solution; it ought not to be beyond the wit of man to invent neutralizing agencies. He maintained that police powers were very limited and difficult to apply.

R. McGlashen (South of Scotland Electricity Board) in a written contribution on the paper by Messrs. Styles and Wilford, said that he was astonished that the authors as engineers should have seen fit to claim that there was a relationship between atmospheric pollution and the efficiency of a fuel/mechanical energy process.

Energy losses in electricity supply were chiefly the irrecoverable heat loss in steam, the mechanical and electrical losses in the transmission and distribution systems, none of which losses contributed one iota to pollution of the atmosphere. In hydro and in nuclear generation there were no products of fuel combustion whatever to get into the air, and in coal and oil-fired generating station the efficiency of combustion was exceptionally high. Furthermore, plant which was usually installed to trap the grit allowed only a minute fraction of it to get through and even that was usually discharged hundreds of feet above ground level and dispersed in the upper atmosphere. This should be compared with the exhausts from road vehicles which were discharged at face level in crowded streets.

Although he had mentioned the above points relating to electricity he was not supporting in any way the statement that there was a relationship between efficiency of a fuel/mechanical energy process and the degree of atmospheric pollution, such a statement he considered to be an engineering absurdity and pointed out that internal combustion engines alone had five different measures of efficiency—Mechanical — Thermal — Standard —Relative and Overall efficiencies.

S. N. Duguid (Individual Member) said he had read these exhaustive and somewhat exhausting papers about exhausts and was reminded of a previous meeting of the Society at which the danger of emitting carbon monoxide was emphasized and the emission of " black, filthy smoke discharge that seriously hampered visibility to motorists on the road " was condemned.

The remedies advocated by those present included (i) eliminate motor traffic altogether; (ii) improve the design of internal combustion engines; (iii) vertical exhausts; and (iv) use of a catalyst to oxidize the CO. The date of that meeting was 3rd June, 1932!

Apparently little progress had been made since then—we seemed to be going round in a circle.

As far as his information went, it had never been proved that the concentration of CO had ever reached a dangerous level in our streets though, of course, anything might happen in the Blackwall tunnel or even the Mersey tunnel if the ventilating system broke down. In the light of present day knowledge it seemed that little could be done about the CO, but we must wait until our scientists had carried out further investigations.

With regard to the elimination of the " black filthy smoke," Mr. Duguid suggested that the only way of dealing with it was to give the Police power to write a notice on the spot ordering the vehicle to the nearest repair depot.

H. E. Styles, in replying to points raised in respect of the paper by Mr. Wilford and himself, stated that, with regard to the points raised by Mr. Dale, he would not wish to dissent from the view that smoke from domestic chimneys contributes more to atmospheric pollution than modern power stations. It also had to be conceded that exhaust from vehicles is emitted at a low level but the rate at which such exhaust becomes diluted with air is surprisingly high.

In making comparisons between electrically propelled and internal combustion engine propelled vehicles, it is very necessary to bear in mind the facts that, at the present time, atmospheric pollution arises from many causes other than vehicle exhausts and moreover it is not conceivable that electrically propelled vehicles could be employed for many of the purposes for which internal combustion engined vehicles are used. The substitution of a small proportion of the latter by electrically propelled vehicles would, therefore, not result in any significant change in the level of atmospheric pollution. It is also necessary to remember that many factors other than air pollution have necessarily to be considered in making a decision as to the relative merits of one form of vehicle over another.

With regard to the point raised by Mr. Batey, it was the authors' intention to imply that the maker's recommended pump setting should on no account be exceeded in an attempt to gain greater power output from an engine. Derating of engines should be regarded as an additional precaution to be taken whenever possible.

Mr. Styles stated that he did not regard himself as competent to comment upon the medical points raised by Doctor Tomlins. London Transport had, however, provided the Medical Research Council with every facility for conducting investigations, the results of which had so far failed to show that air pollution arising from diesel engine exhausts was notably hazardous to health. Nevertheless there was no intention to relax efforts to reduce such pollution to a minimum.

The reference to the greater volume of exhaust emitted by diesel engines could be misleading as the greater volume is merely a reflection of the fact that a diesel engine can be operated with a large excess of air. The greater exhaust volume is thus attributable to dilution of combustion products with air which cannot in itself be regarded as an objectionable feature. For a given power output the diesel engine consumes fuel at a lower rate and produces a smaller quantity of actual combustion products than an equivalent petrol engine.

The remarks made by Mr. G. C. Smith regarding London Transport's vehicles were appreciated. Every endeavour is made to prevent operation in service of vehicles emitting objectionable smoke but isolated occurrences could not entirely be obviated. If desired, notification of any such vehicles observed in service could be made to the Public Relations Officer at 55 Broadway, who would convey any information provided to the right quarters.

Finally, with regard to the written contribution from Mr. McGlashen, it would seem that some misunderstanding of the paper may have occurred.

The main point which the authors wished to make was that other things being equal, a heat engine which consumes a smaller quantity of fuel per unit of useful power output must be potentially less likely to cause air pollution than one with a lower overall efficiency. The argument naturally cannot be applied to the generation of power by devices not dependent upon combustion of fuel and account must also be taken of other factors such as location and the precise nature of the products of combustion emitted. Whatever else might be said internal combustion engines on vehicles certainly cannot be accused of giving rise to pollution of the atmosphere by grit.

The Administration of the Clean Air Act, 1956

(1) SOME POINTS ON ITS PRACTICAL APPLICATION

By

M. Lindsay Taylor, LL.B. (Lond.)

Town Clerk, Tottenham

General Administration

1. In Circular 64/56 the Ministry of Housing and Local Government stated that " the provisions now brought into force by the Order " (i.e. Clean Air Act, 1956 (Appointed Day Order 1956)) " deal *inter alia* with the installation of new furnaces, the height of chimneys, smoke control areas, pollution from colliery spoil-banks, research and publicity, and the making of building byelaws." The remaining provisions of the Act relating to dark smoke and grit and dust from furnaces will come into force on a date, according to the Ministry, " in the earlier part of 1958 ".

2. Local authorities should, therefore, be in a position now to plan the administrative arrangements they think will best suit the needs of their areas, and many will no doubt have already done so. Those in industrialised urban areas will of course need to give the most thought to this question.

3. So far as local authority members are concerned, the functions of the Act are, in the main, so closely connected with Public Health that the Public Health Committee would be the obvious choice of a Committee to which the work of administering the Act should be entrusted. Except in very large authorities and in areas where sub-committees are freely utilised, it should not be necessary for a sub-committee to be specially set up for this purpose. Some Councils, it is believed, have appointed a special Committee for the purpose of discharging Clean Air functions, but such appointments are hardly likely to be common.

4. Irrespective of what committee arrangements are chosen it is practically certain to be the Public Health Department which will carry the heat and burden of the day in the Act's practical application. Indeed without the Medical Officer of Health and the Public Health Inspectors no authority could tackle this work. It will, however, result in a substantial additional burden for those officers and the opportunity should be taken of reconsidering the distribution of the duties and responsibilities of the staff concerned, in the light of the new responsibilities for dealing with atmospheric pollution.

5. Although duties of inspection will be much increased when the Act has been wholly brought into operation there is already much detailed work to be undertaken where Smoke Control Areas are sought to be established, (paragraphs 43 to 46 of the Ministry's Memorandum on Smoke Control Areas* forwarded

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* hereinafter called " Memorandum S.C.A."

with Circular 64) including at least one visit to each premises proposed to be included in the Order. It may be advantageous for the Engineer and Surveyor's Department, which may be concerned with Building Byelaws, to make joint inspections in this particular instance, by means of their Building Inspectors or Building Surveyors for the purpose of preventing overlapping visits. This might also be useful in connection with inspections of works of adaptions carried out by owners or occupiers after the confirmation of an Order.

Close co-operation between all Departments of the authority, coordinated where appropriate by the Clerk, is in any case essential if the detailed administration of the Act is to be smoothly carried out, particularly in the case of Smoke Control Areas.

6. In other circumstances liaison with outside interests is necessitated by various provisions of the Act and the suggestions in the Ministry's " Explanatory Memorandum on Miscellaneous Provisions "* as in the following cases.

New Furnaces. Here the plans (if the applicant desires to submit them) will go to the Engineer and Surveyor's Department, but consultation is necessary with the Public Health Department (para. 9 Memorandum M.P.). Under para. 10 an outside opinion is suggested as being desirable in some cases and also reference is made to the appointment of advisory panels.

Height of Chimneys. Plans of chimneys will also go to the Engineer and Surveyor's Department and similar remarks apply.

Alkali, etc. Act, 1906. Under Section 17(1) virtually all forms of pollution from premises controlled under the above Act are subject to control by the Alkali Inspectorate. When, however, Sections 1, 5 and 16 of the Clean Air Act are in operation, local authorities will be able, subject to the Minister's consent, to take proceedings for offences under these Sections. Also the local authority may apply for an Order removing premises controlled under the Alkali Act from the ambit of Section 17(1) (Memorandum M.P., paragraphs 20-24).

Colliery Spoilbanks. The former Public Health Act powers of local authorities are replaced in the main by section 18 of the Clean Air Act (except for old deposits disused at the passing of the Act). The Memorandum M.P. refers to the special study of the problem by the Alkali Inspectorate over many years and invites local authorities to consult with the Alkali Inspectors and to take advantage of their experience in dealing with the technical problems which arise (para. 31).

Crown Premises. Where an interest belonging to the Crown exists but the Crown is not the occupier of the premises, the Act as a whole will apply, but where the premises occupied for the public service of the Crown or for the purposes of a Government Department are within a Smoke Control area it will be the local authority's duty, in proper cases, to report emissions of smoke to the responsible Minister. Where premises occupied by a visiting force, as defined in the Visiting Forces Act, 1952, are concerned, the report is to be made to the Government Department responsible for the occupation of the premises (Memorandum M.P. paragraphs 34 to 37).

Research and Publicity. The powers of local authorities as extended by Section 25 of the Clean Air Act will enable research and publicity work to be undertaken in relation to the problems of air pollution in the following ways:—

(*a*) undertaking, or contributing towards the cost of, investigations and research;
(*b*) arranging for the publication of information;
(*c*) arranging for lectures and addresses, and holding discussions;
(*d*) displaying pictures, films or models, and holding exhibitions;

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* hereinafter called " Memorandum M.P."

(*e*) preparing, or joining, or contributing to the cost of preparing films, models or exhibitions to be displayed or held under the preceding sub-paragraphs.

While local authorities' Health Departments will already have had experience of arranging Public Health exhibitions and similar local events in a number of cases, the widened powers will involve collaboration on a wider basis with the other appropriate officers of the local authority, including Public Relations and Information Officers and in seeking the co-operation of the local press in connection with such arrangements.

Joint action between local authorities

7. Here several possibilities will need consideration. First, the total relinquishment by several authorities of all their powers under the Act to a Joint Committee under the Local Government Act, 1933, Sections 91—and, in London, 97—and Clean Air Act, Section 31 (5); secondly, the combination of two or more local authorities for the purposes of declaring an area to be a smoke control area for the whole or a part of their districts (Clean Air Act, Section 31 (3)), and, lastly, an exchange of information between adjoining local authorities with a view to co-ordination of effort (Memorandum S.C.A., para. 34).

Joint Consultations

8. Action by local authorities is still proceeding, and, at the date of preparing this paper, the writer understands that the following consultations are taking place or have been suggested:

(*a*) Metropolitan Borough Councils with a common boundary to the City of London (Finsbury, Holborn, Shoreditch, Stepney, City of Westminster, Bermondsey and Southwark).

(*b*) Chislehurst and Sidcup Urban District Council with Woolwich, Lewisham, Bexley, Bromley and Dartford Municipal Boroughs, Orpington Urban District Council and Dartford Rural District Council.

(*c*) Wrexham Municipal Borough and Wrexham Rural District Council.

(*d*) Royton (Lancs.) Urban District Council and adjoining authorities.

(*e*) Croydon County Borough and adjoining authorities.

(*f*) Middlesex Borough and District Councils' Association.

(*g*) Edmonton Municipal Borough and adjoining authorities.

(*h*) Leyton Municipal Borough and adjoining authorities.

Lastly, all the local authorities in the geographical county of Warwickshire (with the exception of the City of Birmingham and two rural district councils) have joined together in establishing the " Warwickshire Clean Air Council " which is an advisory and technical body with the object of abating the pollution of the atmosphere and of assisting member authorities to implement the Clean Air Act, 1956.

Acknowledgment

9. I am indebted to my colleagues in various boroughs and to Mr. H. Kapps, Information Officer to the National Smoke Abatement Society, for the information appearing in paragraph 8 of this paper.

(2) A CRITICAL SURVEY

By

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Since the Society may claim to be one of the parents of the Clean Air Act, it is understandable that you should have a natural interest in the health of this baby.

We know from experience that when he becomes an adolescent we will alternate between rage and sorrow at his shortcomings, and it may now be advantageous to try to make a calm and unbiased assessment of his merits, even at this early age.

Certainly the period of gestation has been a long one. Coal has been mined in England for well over a thousand years, and throughout that time men have warmed their hands at its glow and blackened their lungs in its smoke. Suspicions about its damaging effect on health are not new. Writers have complained about it from the days of that eloquent but long-winded disciple, John Evelyn in 1661[1] to the annual report of the Medical Research Council for 1956[2]. William Farr, the father of Medical Statistics, in the first report of the Registrar-General in 1839[3] commented on the higher incidence of tuberculosis in towns as compared with country areas, and concluded that:

> " the source of the higher mortality in cities is to be found in the insalubrity of the atmosphere."

Ten years later Sir John Simon in his first report as Medical Officer of Health to the City of London[4] said:

> " I would likewise beg leave to suggest whether it might not be practicable for your Honourable Court to regulate the operation of establishments which evolve large volumes of smoke. The exterior dirtiness and dinginess of London depend mainly on this cause; and the same influence, by rendering domestic cleanliness difficult and expensive, creates an additional impediment to its cultivation. People naturally despair of cleansing that which a day's exposure to the atmosphere blackens again with soot; or they keep their windows shut, breathing a fusty and unwholesome air, in the hope of excluding the inconvenience. Now when it is remembered that all the smoke of London is but so much wasted fuel, it must surely be felt that the enforcement of measures for its consumption would be of interest to all parties; amply economizing to the manufacturer, whatever might be the trifling expense of appropriate arrangements, while it would relieve the public of that which, called by the mildest name is a nuisance and a source of heavy expense."

Modern Public Health Officers will doubtless understand his feelings when more than forty years later he records that there has been no improvement.[5]

> " There are immense masses of our population, the inhabitants for instance, of London and of many chief manufacturing towns, who endure without revolt or struggle the extremeties of general Smoke Nuisance; not only condoning the fact that the nuisance is of painful injury to an appreciable proportion of persons, and in certain states of weather kills many of them; but further accepting, as if in obedience to some natural law, that their common life shall in great part be excluded from the pure light of day—that incomparable source of all physical gladness—by an ignoble pall of unconsumed soot; "

How Simon would have welcomed the resolution of his Honourable Court passed on 2nd October, 1955, declaring the City of London a Smokeless Zone some 107 years after the advice contained in his first report to them.

The " insalubrity of the atmosphere " has, on occasions been responsible for a marked increase in the death rate, and the Meuse Valley incident in Belgium in 1930, when more than sixty people died, the serious fog at Donora, Pennsylvania in 1948 when eighteen people died in a fortnight, seventeen being on the fourth and fifth days after the onset of the fog, and in 1952 when the most serious fog on record was responsible for almost 4,000 deaths in London[6], are the best known examples.

No-one would welcome such outbreaks, but it is easier to measure the damage they cause than it is to assess their effect on the public conscience. Many of our cities owe their pure water supply to the fear engendered by an outbreak of cholera, and the early nineteenth century drive for improved sanitation gained its impetus less from compassion for the victims than from an ever present fear for the safety of the persons of those in authority. There is reason to think that the 1952 London fog was felt in Whitehall as well as in Smithfield. Unfortunately, men are much more interested in the results of air pollution than in its causes, and the alarm and indignation provoked by a bad fog tend to be dispersed with the first wind that blows. The new Act is a most welcome sign that we have at last abandoned a policy of piece-meal curative measures which have shown little result and are now committed to a new policy which is both positive and preventive, based on the establishment of Smoke Control areas.

Smoke Control Areas

The Smoke Control area is the backbone of the new attack on air pollution. It is the first organized attempt to tackle the problem of the domestic chimney and the approach is a positive one. The development of the slow combustion domestic grate suitable for burning smokeless fuel is one of the most promising post-war advances in housing and the fact that they will rank for grant should do much to overcome opposition to the declaration of a smoke control area. No doubt the cry of liberty will be heard in the land, but the liberty to pollute one's neighbour should at least require a licence.

The principle laid down in the celebrated case of Rylands *v.* Fletcher in 1868,[7] and succinctly stated as " He whose filth it is must keep it in," is a sound principle. The smoke control area is no more than a practical application of that rule. Our neighbour has no more right to pollute the air we breath than he has to foul the water we drink and he should be held responsible if he transgresses in either respect.

The smoke control area is undoubtedly right in principle but it may be open to question whether the accepted method of operating the rule is the right one. The present general tendency is to confine such an area to the business centre of cities where its provisions can most readily be enforced. This will inevitably result in a small smoke-free area being surrounded—and it may well be obscured—by heavy pollution from a highly industrialized vicinity. It is suggested that a smoke control area should be at least large enough for the inhabitants to see a positive benefit from their abstention. The innovation of a green belt is now well established as a desirable and generally accepted feature of town planning. Can we now enforce a fresh air ring around our cities, extending gradually towards the centre? Suburbia has normally little industry and might well be an area where good results would most readily be seen and appreciated. By a similar process of reasoning is there not an argument for dealing with areas, first, where little smoke is produced? In a rural county the pollution from a single chimney is a more obvious desecration of the landscape than is a smoky chimney among its fellows in an industrial area. Air pollution is a problem within the wide field of preventive medicine and the prevention of new sources of pollution is at least as important as the elimination of the existing ones.

Administration

Mr. Marsh in his text-book says[8], " If we are to make a final assault, on a requisite scale, on air pollution, it will be necessary to survey the organization needed to direct and administer the operation."

The Beaver report[9] recommended that the powers of the Alkali Inspectorate be extended to include smoke prevention from the scheduled processes, but that the general administration of the Clean Air Act should remain with the Local Authorities.

> " We have considered, but discarded, suggestions that more satisfactory results would be achieved if the duty were placed upon some other body, e.g. the national board, regional boards, or county councils. Although it is true that air pollution knows no boundaries, its origins are local, and with certain exceptions we consider that prevention can best be enforced by the local authority on the spot."

I would submit that this is the least satisfactory part of an otherwise excellent Report. A system of administration which has a civil servant standing watching one chimney while at the same time a local government officer is keeping an identical vigil on the chimney next door can hardly hope to escape criticism. The relationship between the Alkali Inspector and the Public Health Inspector, cordial though it is, should rest upon a more stable foundation. I would submit that the Public Health Inspector is a general practitioner and the Alkali Inspector a specialist in the work of air pollution and there is undoubtedly need for both kinds of officers. But the very nature of the relationship requires that they should not work independently, but as equal partners in a team of experts.

As between the Central and Local Government there seems to be no doubt that we, as a nation, prefer Local Government, and any further extension of the Central powers would probably be vigorously resisted. Even if it is generally agreed that the duty is one for local government there remains a wide scope for argument as to which type of authority should discharge it. No answer can be given to this question without considering the future structure of local government and the availability of trained staff.

The present government has recently published a white paper on Areas and Status of Local Authorities in England and Wales[10]. It is not the most satisfactory of documents. It seems uneasily aware of the need for reformation, but lacks the zeal of the reformer. It is said to be based on agreed proposals but as all the parties to the agreement were clearly united in their determination to yield nothing the result hardly lives up to the Minister's description " a bold and comprehensive overhaul." To complicate matters further there seems to be some doubt as to what was, in fact, agreed. Professor Finer has said,[11] " the agreed proposals are often so obscure or ambiguous that they permit considerable re-interpretation."

The problem of the conurbation is stated, but not resolved. Their complexity is well illustrated by the fact that the South Lancashire wen casts it shadow over two counties, seven county boroughs, fifteen non-county boroughs, twenty-nine urban districts and one rural district; the last must surely suffer from a feeling of claustrophobia. On the problem of the conurbation—a better title would be the adjective metropolitan—we seem to be no nearer the solution than we were after the Tyneside Report in 1934[12] when a bold solution was rejected by a government bent on a policy of appeasement. Since that time the Ministerial contribution to solving the problem of the conurbation has been confined to alternately shaking the head and scratching it. We are now promised two Local Government Commissions and a Royal Commission, the latter " to examine the present structure and working of local government in the Greater London area," and it is to be hoped that the Minister's description of his policy may be at least prophetically accurate.

It is agreed that the conurbation—that ugly manifestation of the herd instinct—is clearly unsuited to be an all purpose authority but the fact that a Metropolitan Authority cannot perform every service is not an argument against permitting it to perform any service. The largest conurbation of them all—London—is an efficient local authority unit for at least two services, police and water, and both these duties are carried out with commendable efficiency. It is interesting to recall that a Metropolitan Police Force was proposed as long ago as 1785 in a Bill introduced by Pitt but was rejected, largely through the opposition of the City of London, whose alderman felt that their authority would be threatened by it. The Force was eventually established by the Metropolitan Police Act of 1829 which closely followed Pitt's Bill, but prudently excluded the City of London from its effects.

Similarly, the Metropolitan Water Board was created in 1903, when it took over the undertakings of the eight water companies which were then supplying London with water.

I would claim that these two examples show that a Local Government unit with a population of several millions is not necessarily too large for efficiency if confined to specific and suitable objects. Smoke is no more local than crime or the need for a pure water supply and it is submitted that there is a need for a number of Metropolitan Clean Air Boards, administered by joint representatives of the Local Government areas served by the Boards, and covering each of the present conurbations. The officers serving such a Board would include a Medical Officer of Health, a Combustion Engineer, an Alkali Inspector, two representatives of local industry, a member of the Clean Air Society and a representative of the Ministry who could, if thought fit, attend as an observer.

Staffing

No real advantage will come from the new Act unless we face the unpleasant fact that its benefits will have to be bought for the community in hard cash. This will mean, in the first place, more Public Health Inspectors trained in the technical work of smoke abatement. The Royal Sanitary Institute was the pioneer in this field, as in many others, and was advocating examinations for Smoke Inspectors as long ago as 1908 and ran the first examination in 1914. Since that time over a thousand candidates have qualified and the annual number is increasing each year. In 1956, fifty-four candidates were successful (a record number), and it seems certain that this pass list will be exceeded next year.[13] Even so, the output is clearly inadequate to meet the demands of the day. The recent working party Report on the Recruitment, Training and Qualification of Sanitary Inspectors said[14]:

> "Smoke abatement, or atmospheric pollution, is a subject to which increasing attention is being given. It is clear that the full duties which may be performed by a sanitary inspector in relation to atmospheric pollution call for a high degree of technical knowledge. While this work is more extensive in large industrial towns it cannot be ignored in rural districts especially in view of the modern tendency to disperse industry."

It also found that 57 per cent of Sanitary Inspectors gave no time to this duty and only 2·2 per cent of inspectors spend more than 50 per cent of their time on this work. It may well be that owing to the extreme shortage of inspectors a high proportion of their time had to be devoted to more urgent claims.

It is nevertheless clear that either many more inspectors will have to be trained in smoke abatement or this function concentrated among fewer inspectors.

Clean Air Councils

The success of such bodies as the Central Housing Advisory Committee, ensures that we will extend a welcome to the Clean Air Council, which has now been formed. There are already a considerable number of organizations with objects of a substantially similar kind including the Department of Scientific and Industrial Research, the Coal Utilization Research Association, the Solid Smokeless Fuel Federation and the National Coal Board, the British Electricity Authority and the Society for Clean Air, and there is clearly a need for co-ordination of the activities of these various bodies so that their energies may be put to the fullest use. I would suggest however, that the need today is not for more research—important though that is—

tion must take time to gather up the required momentum, and a great deal cannot be expected during this, its first year. The question is therefore not what has been attained so far, but rather what indications are there that the requisite rate of progress is going to be attained, and when. It is on this basis that an attempt has been made to prepare this progress report.

Plans for Control Areas

As far as is known, over a hundred local authorities are considering plans for smoke control areas, and over thirty Orders have been drafted and submitted to the Minister for approval. As far as numbers are concerned, this may be regarded as a satisfactory beginning, but as far as can be seen, the acreages, or number of houses and other premises, involved are very modest, so that the aggregate area falls very short indeed of the annual target of 300,000 acres, or 1·5 million tons of coal replaced. This may well be, in part, because local authorities consider it desirable to start with small pilot schemes, but it also seems likely that in many cases the cost of grants for conversions is causing misgivings, which are leading to a very cautious and slow-moving policy. The burden on the rates can be seen, only too plainly; the savings due to cleaner air, in cash, health and amenities, are more difficult to appreciate and accept. It is still not generally understood that it is much cheaper to spend money on clean air measures than not to do so.

Another reason that appears to be holding back at least a few local authorities is that until the Clean Air Act is fully operative in respect of the control of industrial emissions, it would be inexpedient to take action against domestic smoke. One authority, in fact, has shelved a scheme for a smoke control area on the mistaken grounds that they will be unable to take any action at all against industrial smoke until the end of the temporary (seven years) defence relating to structural changes.

Finally, some authorities appear to be moving more cautiously than they should because of uncertainty about the availability of smokeless fuels, perhaps because of local difficulties affecting certain fuels. This point takes us to the second of the factors being considered.

Availability of Fuel

The problem of supplying smokeless methods of heating to the whole of the black areas, through the progressive extension of smoke control areas, was fully discussed in the Beaver Report, and has been further amplified in many recent papers and discussions, and it is not necessary here to recapitulate the requirements that have been indicated.

Although smokeless solid fuels remain the key factor, it is desirable not to overlook the other types of fuel and power which, the more they are used, will reduce the level to which solid fuel production must be raised.

Gas, electricity and oil are the smokeless mediums that can be used, in various ways, in smoke control areas. If they are used *in place of*, as distinct from being used *in addition to*, raw coal, they are directly assisting in the solution of the problem of providing enough solid smokeless fuel to take the place of the discontinued coal. We are informed by authorities concerned with each of these fuels that they can expand supplies to meet all likely demands. For the gas industry, for example, we are told that:

> " As soon as a firm trend in demand for smokeless fuels can be distinguished, the industry can review its present plans for gas and coke production so as to allow for a larger output of both."

One of the Area Gas Boards stresses the possibilities of increasing the domestic use of gas by means of two-part tariffs:

> " The Board are endeavouring to promote additional sales of gas, particularly for space-heating purposes, through the introduction of promotional two-part tariffs for domestic consumers. The extent to which gas

> will be used to replace solid fuel will depend to a great extent on the success or otherwise of these promotional tariffs. Although in many circumstances gas is cheaper for living-room heating than the conventional coal or coke fire, the traditional public preference for the open fire has to be overcome."

Electricity can also be made available for a considerably increased space-heating load, but the extent to which it will be so used, again in place of raw coal, in smoke control areas depends in part on its price, as with gas, and in part on the method to be used. It is hoped that the gradually increasing proportion of power from nuclear stations will tend to reduce costs, but equally important is the question of the load factor. We are informed that:

> " Electricity Boards wish to develop off-peak loads, and we would prefer it if all our new space-heating load were of an off-peak character. In consequence, we take an active interest in the development of electrical floor warming, which is ideal for new buildings.
>
> " As regards existing premises, the block storage heater is the only really successful answer to the problem, but unfortunately at present it can only be sold for installation in commercial and industrial premises due to purchase tax restrictions. I believe the Treasury have this matter under consideration, and we are hoping that it will soon be possible to install block storage heaters in all types of buildings."

The use of oil for domestic purposes is growing, both for central heating and for individual convection heating, and this trend may so develop and become popular that a useful load can be taken by oil in the smoke control areas. Ample supplies are said to be available, or can be made available, for any demands likely to be made.

The most generous estimates of the parts that may be played by gas, electricity and oil in the smoke control areas still leave a substantial problem of production and distribution of solid smokeless fuels, which must be solved if the smoke control areas are to come into being at the rate indicated at the beginning of this report.

It is not easy to sum up the solid fuel situation clearly and concisely. Much is said about the availability of solid smokeless fuel without reference to whether the statement refers to the situation (*a*) as it is now; (*b*) as it will be when the present modest schemes for smoke control areas are put into operation; or (*c*) as it would be if progress were being made at the desired rate of 1·5 million tons of coal replacement per annum.

Much is said about shortages of smokeless fuel, which generally prove to relate either to purely local shortages, temporary shortages, or shortages of the special, or named, fuels, the production of which is more circumscribed than that of coke.

On the other hand, statements are made that adequate supplies of smokeless fuel are available, and these usually refer to local or temporary surpluses of coke, such as those likely to occur after a mild winter.

A recent Parliamentary reply to a question on smokeless fuel production is of interest:

> *Mr. Nabarro* asked the Paymaster-General the output of smokeless fuel in the United Kingdom during the last year for which figures are available; and what estimate he has made of the prospective output of such fuels during each of the next five years.
>
> *Mr. Maudling:* Total production of solid smokeless fuels in 1956 was about 34 million tons, excluding hard coke supplied to blast furnaces and foundries. Production in 1957 will probably be at about the same level. In subsequent years it will largely depend upon demand and I have no reason to believe that shortage of supplies will delay progress under the Clean Air Act, 1956.

Here again may be noted the reference to future production largely depending on demand, and the uncertainty as to whether progress under the Clean Air Act means progress at the present rate or at the greatly accelerated rate that is hoped for. The 34 million tons of fuel mentioned includes the natural smokeless coals as well as coke and the named fuels.

Only about 5 to 6 million tons of the total is used for domestic purposes.

The absence of precise factual information on the situation that should be emerging is further illustrated by Parliamentary questions and answers on 15th April last:

Mr. Moyle asked the Paymaster-General the tonnage of natural solid smokeless fuel, manufactured solid smokeless fuel, other than coke, and smokeless briquetted fuels produced in 1954, 1955 and 1956 respectively; and what is in his view the estimated total tonnage necessary to implement the provisions of the Clean Air Act, 1956.

The Parliamentary Secretary to the Ministry of Power (*Mr. David Renton*): About 17 million tons were produced in each year. The smokeless fuel requirement under the Clean Air Act will ultimately be met by coke, other solid smokeless fuel, electricity, gas and oil, and it is impossible to estimate how much of the various fuels will be required.

Mr. Moyle: May I conclude from the Parliamentary Secretary's statement that there is sufficient smokeless fuel for the purposes of the Clean Air Act? If so, and having regard to the fact that domestic consumers of smokeless fuel will have a big part to play in ensuring clean air, will the hon. and learned Gentleman explain why domestic consumers have to wait for months before they can get a hundredweight of smokeless fuel?

Mr. Renton: The last part of the hon. Member's supplementary question raises a distinct point. I assure him, however, that bearing in mind that it will inevitably take some years wholly to implement the Clean Air Act, we are confident that with increased production of the various fuels that will be needed, the requirements of the Act will be met.

From the various generalized statements quoted above, it is possible to draw only generalized conclusions, but before doing so the situation with respect to the different types of solid smokeless fuel may be briefly reviewed.

Gas coke must, of course, continue to supply the greater part of the required solid fuel, and, as has been noted, steps to review increased production will be taken " as soon as a firm trend in demand " is apparent. We can expect coke to be increasingly assisted by increasing production of the named fuels, including, it is hoped, the more freely burning " super cokes " of the Phimax and Cleanglow type. Production of Coalite and Rexco is also increasing, and for 1957 it is expected that 550,000 tons of Coalite and 100,000 tons of Rexco will have been produced. Plans for further increases in output of both these fuels are mentioned in the current issue of *Smokeless Air.* It should be emphasized that all these free-burning fuels are suitable for any type of open fire and can therefore be used in smoke control areas without conversion of appliances.

The production of Phurnacite and hard (or oven) coke, both mainly used in closed appliances, is also increasing. In 1956 nearly 4 million tons of hard coke were sold for domestic and industrial purposes, and the improved availability of Phurnacite is shown by the following annual production figures:

1955	317,000 tons
1956	384,000 ,,
1957	640,000 ,, (capacity)

The possible development of new types of smokeless fuel, on which work is being done by the National Coal Board, must not be overlooked. Some increased availability of anthracite and other low-volatile coals may be hoped for as production in South Wales is improved. There is a projected increase in annual output of 2·5 million tons of coal in the South-West Region of the N.C.B. for the period to 1965.

It had been hoped to indicate something of the regional variations in present supplies and future prospects that appear to exist, but it has not been possible to obtain enough information to make possible any useful analysis. An exception is the case of Scotland, where there is a shortage of carbonizing coal and an absence of plant for the production of the more free-burning fuels. The transport of smokeless fuels from England or Wales to Scotland adds materially to their prices. The problem deserves closer attention, including an examination of the possibilities of developing the production of processed peat, to give dry, compressed briquettes, as discussed in an article in the Summer, 1957 issue of *Smokeless Air*.

Problems associated with the distribution and domestic storage of solid smokeless fuels were raised at the last conference of the Society. They are concerned mainly with the regular supply of small quantities and the difficulties that arise when consumption rises steeply during spells of very cold weather. These are essentially economic questions; improved facilities for distribution must entail higher distribution costs, which are bound to be reflected in the price charged to the consumer. The question as it concerns flats is admirably examined in a report of an inquiry by a joint committee of the London Regional Committee of the Coal Utilization Council and the Institute of Housing, entitled *The Delivery and Storage of Solid Fuel in Flats*.

The conclusions that may be drawn from this report may be summed up as follows:

1. The general situation has not changed to any significant extent since it was analysed by the Beaver Committee, especially in the Appendix to their report by the late Dr. G. E. Foxwell. It is not yet possible to say whether the developments that are now being made, or are probable in the near future, are adequate for the desired programme.
2. There is likely to be enough of all kinds of smokeless fuel to meet the needs of the smoke control areas at present being planned.
3. Increased production in a major sense will follow only from increasing pressure by local authorities seeking to create smoke control areas at a rate more nearly approaching the coal-replacement target of 1·5 million tons a year.

Really satisfactory progress depends, in short, on local authorities planning smoke control areas on a scale which, because they threaten to cause a real shortage of smokeless fuel, may have to wait for some years before they can be established. It is quite wrong for local authorities to defer their plans for smoke control areas until the supplies of smokeless fuel are more certain. It must be remembered that Orders will not be given Ministerial approval unless fuel supplies are adequate, and a long queue of such Orders waiting for approval is perhaps the best way of ensuring that production is being continuously expanded.

This report has been prepared by the Director on the instruction of the Executive Council, but the views expressed are not necessarily those of the Council.

Discussion

M. Lindsay Taylor, in introducing his paper, made a special reference to that part of paragraph 6 of the paper which related to the Alkali, etc. Works Regulation Act, 1906. Mr. Taylor pointed out that the Beaver Committee had recommended that smoke control should be added to the duties of the Alkali Inspectors and that the number of industries scheduled to that Act should be extended. The Minister had announced in October, 1956, that he was proposing to bring a number of new processes within the Alkali Acts by an Order to be made under Section 4 of the Public Health (Smoke Abatement) Act, 1926. These were metallurgical works, power stations, gas works, coke works, ceramic works and lime works. This extension, if made, would, of course, reduce the powers of local authorities in relation to smoke emissions from the industries mentioned by depriving them of the right to prosecute in such cases without the consent of the Minister.

Mr. Taylor pointed out that a local Inquiry had been held in May and June last into this proposal when the leading manufacturers, trade federations and Boards concerned with those industries had appeared in support of their representations, and the Association of Municipal Corporations and the Sheffield and District Clean Air Committee appeared in opposition. The Minister's decision was still awaited.

W. R. McGrath (Association of Public Health Inspectors) said that Mr. Don in his paper had included an extract from one of the many reports of Sir John Simon. Having regard to Lord Mills' reference the previous day to education as being of primary importance in the abatement of atmospheric pollution, it might be of interest to note that in another of Sir John's reports he had written of " the incalculable good of an education which would teach people to feel the comfort and profit of sanitary observances."

Mr. McGrath referred to the paragraph in Mr. Don's paper headed " Staffing," and suggested that whilst the problem of the shortage of Public Health Inspectors should not be minimized, neither should it be exaggerated. The attractions of industry and the call-up of young men were among the causes, but they affected other departments of the Town Hall especially those employing technical staffs.

The General Council of the Association, and the generality of its members had done, and were continuing to do, much to remedy the position. It was largely a case of history repeating itself.

Before the end of the last war a dearth of Public Health Inspectors had been anticipated by the Council of his Association. On its initiative and with the support of the Ministries of Health, Education, and Labour, a scheme for the training of ex-Service personnel had been successfully operated. The scheme was the first and he believed the only one embarked upon by any professional organization. So successful had it been for a time there had been a measure of unemployment among qualified Inspectors.

When the decline had set in—and that had been largely the result of the unfortunate so-called interim decision of the National Negotiating Body dealing with the salaries of Inspectors—the effect of which was still with us—the Association had turned to other means to stimulate recruiting.

For years the Association had pressed for a scheme of articled pupillage and in more recent times for paid pupillage, and as a result of its representation the Working Party on the Recruitment, Training and Qualification of Sanitary Inspectors had recommended to the Minister of Health that the paid pupillage scheme should be adopted. The Government had adopted the recommendation and local authorities had then been asked to put it into operation.

Mr. McGrath gave some figures to illustrate the position more clearly. In the six years 1947-52, 1,771 candidates had been successful in the Board's examination; in 1953-55 only 218 had been successful. In 1956 the figure had risen to 117 and in the current year to date 105 had passed the examination. The latter figure would increase by the end of the year and showed an improvement on the 1956 figure.

So far as training was concerned some 600 pupils were in varying stages of training with over 1,000 authorities. In the " black areas " referred to in the interim report of the Air Pollution Committee the staffing position was not too unsatisfactory. It was in those areas where the emphasis on smoke abatement must first be placed.

The new Public Health Inspectors Education Board was well advanced in the preparation of a new syllabus of examination and more concrete proposals for the training of pupils. The syllabus was expected to be published shortly and he had no doubt it would be found that, in accordance with the Working Party's Report and the implications of the Clean Air Act, a higher standard of knowledge of smoke abatement methods would be demanded of candidates.

Mr. Don had referred to the Smoke Inspectors Certificate of the Royal Society of Health and Mr. McGrath endorsed all that he had said, but added that many Public Health Inspectors had qualifications obtained by study at Technical Institutes in combustion engineering which were of equivalent value to the Society's certificate.

He looked forward to the day when the Education Board would be responsible for an examination which would enable them to issue a certificate of competency in all the duties of the office of Public Health Inspector.

Local authorities should examine their establishments of Inspectors in the light of requirements for a forward period of say four or five years and plan for the filling of vacancies which would be known to occur in that period. The remedy for the shortage of staff which existed was in their hands.

Mr. Don had quoted from the Working Party's Report of the percentage of time spent by Public Health Inspectors on smoke abatement work, which was misleading. That information had been culled at a time when they had been working under the time-consuming and frustrating provisions of the nuisance sections of the Public Health Acts and the percentages he had quoted were now quite out of date.

R. McGlashen (South of Scotland Electricity Board) said that he would like to supplement certain words of Mr. Marsh's in the Report on " The Availability of Smokeless Fuels "—he wished to say why the Electricity Boards wished to develop a new off-peak load and what they were doing about it, and where space heating came into the picture. He explained that electricity generating plant was expensive; it got outdated in time and should not stand idle for too much of its useful working life if it could possibly be avoided. It was very much in the national interest that electricity load should be developed to a much greater degree than at present in the periods when demand was lowest. That particularly applied when most of the plant was available—that was when the least amount was out of service for overhaul. Both of those conditions were met with every night during the winter and to a lesser degree around midday in the winter.

It so happened that those were the times of the day and of the year when electricity was useful for the very comfortable and inexpensive thermal storage electric space heating, and it followed that a very considerable extension of that load would fit in well with the national interest in more ways than one. They would not have to build more generating stations to meet that type of demand than would be there already. The quantity of electricity available for that purpose would increase steadily, because the quantity of electricity sold doubled every ten years and unless there was a drastic change in the pattern of usage there would be a similar tendency for availability of off-peak electricity to increase in a similar fashion.

The use of electricity in that way led to considerable savings in overall generating costs and those savings were passed on to the consumer in the form of exceptionally low off-peak tariffs—sometimes at less than half the rate of unrestricted tariffs.

With the growth of nuclear power, the position outlined would apply with even greater force. Nuclear generating stations, as at present designed, needed a steady load over each 24 hours, and generating economics even more favourable to the off-peak load could be expected to make tariffs even more attractive.

He hoped that the explanation would have made it clear that the policy of off-peak load development was not merely another attempt to sell more electricity, which was in any case selling itself on economics alone these days. It was an endeavour to shape the load in the national interest.

F. E. Longhurst (North Thames Gas Board) referred to the statement in the paper on " The Availability of Solid Smokeless Fuels " that " these free burning fuels (Cleanglow, Phimax, Coalite and Rexco) are suitable for any type of open fire and can therefore be used in smoke controlled areas without conversion of appliances."

He explained that, although that statement was factually correct, it was, he thought, bad counsel for the individual, the community and the nation. The way ahead lay in the progressive elimination of the old type of fuel wasting domestic stool bottom grate and the substitution of gas ignited coke grates that would be capable of burning efficiently all types of solid smokeless fuels, whether they were traditional cokes or the new type of " super coke."

On such appliances (the cost of which was very low) 16 cwt. of ordinary coke or 14½ cwt. of Cleanglow would do the work of one ton of coal. That approach to the problem of the domestic fire in smoke controlled areas assured a freedom of choice to the individual so far as fuels were concerned and economies in fuel usage both to the individual and the nation. The best advice therefore to all local authorities planning smoke control areas was to avail themselves of the technical help and advice that was freely given by all Gas Boards, on tested types of coke-burning appliances, that, when fitted, would give satisfaction and low fuel costs to the user.

Councillor S. C. Piddington (Willesden) said he would like to speak on the availability of smokeless fuels and their prices, and was pleased to be able to follow Mr. Longhurst of the North Thames Gas Board, because it was on the price of " Cleanglow," the new smokeless fuel mentioned by Mr. Longhurst, that he wished to protest.

He came from a borough that had been the first in the country to insist that all their Inspectors must possess the Smoke Inspectors Certificate, a borough that was over-industrialized by virtue of the fact that it had three power stations within the borough, two power stations right on the boundary, seven marshalling yards, and over 1,000 industries. Willesden claimed that on the question of industry they were making progress, in so far as they had full co-operation with them. They had been successful in getting one power station to convert all their pulverized boilers to oil firing, of which there were now no complaints. They had met Officers of the Central Electricity Authority with regard to another power station which, after discussion, had been closed so as to enable plant modifications to be made, which, he thought, should eliminate any further complaints from that power station. Willesden could, therefore, claim some measure of success with regard to industry.

Councillor Piddington said that his Council had embarked on a campaign of public meetings, to educate its citizens in what clean air meant to them. In that respect they were grateful to the National Smoke Abatement Society through its Director, Mr. Arnold Marsh, who had spoken at their meetings. The Council had recommended to their citizens the types of smokeless fuels that were available, but the latter had found that those fuels were practically unprocurable. He said that the Conference had heard on the previous day from the Minister of Power, Lord Mills, that it was his responsibility to see that the fuels that were required were obtainable, that the quality was right, and that prices were reasonable. That had been the theme of all the conferences he had attended for the past six years. He had heard Mr. David Renton, Parliamentary Secretary to the Minister of Power, two weeks ago at Eastbourne, say the same thing; he had heard Mr. Enoch Powell, Parliamentary Secretary to the Minister of Housing and Local Government, the year before say the same thing, and he was wondering whether they had been sincere in saying they were interested in clean air and would do all in their power to help the Society and local authorities to achieve it. He considered that the Government and the nationalized gas boards were driving local authorities into the hands of vested interest, namely the coal distributors. He said that, because he had had a letter from the North Thames Gas Board saying that the new fuel, " Cleanglow," could only be obtained through certain coal merchants. He had tried the fuel and it could do all that was required; it could save local authorities pounds when they were considering their smoke control areas, in that it could be burnt in any open fire type of grate without the necessity of conversions. But he asked, and he sincerely hoped that the Executive Council of the Society would take note, *at what price* to the consumer? His Council had been informed that the North Thames Gas Board could produce the fuel at a reasonable price, but they had since found that the price as set down by the Minister and the Gas Board had the effect of adding another £1 5s. 10d. per ton, or 2s. 7d. per cwt. which was the price when, and if, delivered by the coal merchants. Was that the *reasonable* price the Minister talked about. Why, Councillor Piddington asked, couldn't the Gas Board distribute the fuel as they did their coke? Were these people sincere when they talked about clean air, when they were driving local authorities into the hands of vested interests? He very much doubted it.

C. A. Watson (Scunthorpe) said he wished to say at the outset that he was a critic of the Clean Air Act. He believed in the saying " Hard case makes bad law " and in his judgment the Act was the result of two factors. Those were the shortage of coal and the London smog of 1952, the Act being the consequence. Indeed, the speech of the Minister the previous day had been such that, without the alteration of a single word, it could have been delivered to a conference of any coal utilization organization.

Further, in the main it dealt only with the consequences of burning solid fuel by two classes of users, industrial and domestic. In so far as industrialists were concerned, incomplete combustion, the prime cause of smoke, was due either to negligence or indifference and the cure for pollution, or at least an almost cure, could be readily attained either by the use of appliances or having well-trained stokers.

In regard to domestic users, these were the most defenceless members of the community and they ought not to be expected to bear the cost of any conversion and, despite the Minister's confident predictions, suitable fuel in the right place could not be guaranteed and he had been very careful to avoid mentioning the very material factor which concerned domestic users, namely " at a reasonable price."

A further criticism was that, apart from poor combustion of solid fuels, the bill was an attempt to deal nationally with a local problem and could not have any real success in any reasonable future and what was a greater weakness it did not attempt to deal with grit and fume emissions which were the result of industrial processes.

Mr. Watson said that he personally was concerned with the conditions in Scunthorpe, a town of under 60,000 population, which used more than two million tons of coal annually in industrial processes. That produced more than two million tons of steel per year, one-tenth of the steel production of the whole country. Expansion had been planned with the result that there were only three industrial chimneys in the town, one in the local laundry, one in the local milk processing establishment.

There were ten blast furnaces turning out over a million tons of iron a year and rather more slag. It could be quoted on good authority that a greater weight was emitted from the top of the furnace than was tapped from the bottom, the emission being gas and grit. Further, there was a growing and developing practice of burning oxygen over or in the bath of the steel furnace which resulted in a dense emission of red oxides from the chimneys. Beside that there were two big slag crushing works from which clouds of dust and grit entered the atmosphere at low levels.

No single section of the Act gave the local authority any power to deal with those matters and Mr. Watson said that he was convinced that in many other authority areas problems of a comparable nature existed, about which they could do nothing. Because of the absence of powers and the complete failure of the Act to deal with processes other than the combustion of solid fuels he urged that the Society should start negotiations with National Societies or Federations of Industries with a view to research and subsequent remedial actions being undertaken so that they in the non-conurbation areas could discuss with local managers the problem of atmospheric pollution resulting from their processes.

The previous week the Iron and Steel Federation had held a conference to which had been invited, amongst others, representatives of the local authorities. At that conference the nature of the problems relating to atmospheric pollution facing the industry had been explained and information had been given as to the steps being taken to minimize the effect of such processes. That he regarded as being an excellent example of the policy he was advocating and one which, if followed by other similar national bodies and if approached in the spirit of co-operation and mutual trust and understanding, could do more to further the aims and objects of the Society than anything contained in the Act.

E. J. Winfield (S.P.H.I., Castleford) said that, amongst other things, he had the honour to be the Chairman of the West Riding Clean Air Advisory Council and in that connection he welcomed the opportunity of supporting Mr. Lindsay Taylor's pleas for joint action by local authorities. The West Riding Committee had been in existence for thirty years and in the last twelve months with the advent of the Clean Air Act, had extended its activities to cover the whole of the West Riding of Yorkshire with the exception of the Sheffield district.

It had always aimed at securing co-operation by local authorities and uniformity of practice. Its latest project was the formulation of a panel of advisers to be at the service of authority members when dealing with prior approval.

Mr. Winfield also said that he would like to support Mr. Graham Don's plea for assistance in the replacement of old type ranges by modern appliances whether it be done in prescribed areas or not. He had raised this point at the Glasgow Conference and had pointed out that at the beginning of the century, it had been appreciated that the presence of privy middens were a threat to the health of the community and, in order to secure their conversion to the water carriage system, legislation had been introduced to enable local authorities to contribute 50 per cent. of the cost of conversion.

Surely, today the presence of out of date appliances was as big a menace as had been the old privy middens and their conversion was just as desirable.

If it was sound policy to contribute to the cost of converting privy middens, it was equally sound to contribute to the cost of converting smoke reducing appliances.

Norman Carr (President, Coal Merchants Federation) said that he was grateful for the opportunity of mentioning two points. One was the vital necessity of interested local authorities ensuring that adequate supplies of *suitable* smokeless fuels were available before a decision on any particular district was made. There was a large amount of coke in stock at the moment, but a very great deal of it was quite unsuitable for open fires. Most people liked open fires and if a decision was lightly taken without the most careful confirmation of supplies the coal merchant would be the first to receive the vast volume of complaints, but what was just as important, the local councillors who initiated the scheme would themselves come in for a lot of adverse comment. It was not a matter of concern to the merchant as he did not mind what he sold, but they must retain public confidence.

The other point was in connection with the previous speaker's comment on " Cleanglow " costing more because it was sold only by private enterprise. Mr. Carr was happy to assure the Conference that the prices charged were rigidly controlled by the Ministry of Power which allowed a very small profit element, and all prices, whether direct from the Board or through a merchant, were exactly the same.

F. A. Driver (Joshua Bigwood & Son Limited) said he had two reasons for wishing to comment on a remark made by Mr. Graham Don when he had introduced his paper.

Firstly, he thought Mr. Don should be congratulated on his shrewdness when he said that manufacturers of appliances for smoke-free burning were biased in what they said. Of course they were. Mr. Driver pointed out, however, that in so far as the industrial field was concerned, that very bias Mr. Graham Don complained of, had been responsible for as much cleaning up of the atmosphere over the last twenty years or so as in all the proceedings of this noble Society.

Mr. Driver said too, that without wishing in any way to enter the lists concerning that part of the Act to be administered by the Alkali Inspectorate, and that to be administered by the local authority, he warmly supported Mr. Don in his suggestion that there should be some central authority to whom appliance manufacturers might look for guidance and advice in carrying on with the good work they had been doing for so long.

Dr. W. C. Turner (M.O.H., Poplar) drew attention to the fact that this was the first conference since the coming into force of the Clean Air Act. The Society was to be congratulated for the part it had played in that great achievement.

One landmark had been reached and with the proposed change of name of the Society there was a need to seek fresh horizons.

Under the Health Welfare and Safety Regulations of the Factory Acts the worker had to be adequately protected from any noxious fume, toxic vapour or dust: too often a safe atmosphere inside the factory was achieved by some form of exhaust ventilation discharging directly to the outside air. Some of the substances so discharged had been responsible for deaths outside the factories, their effect on health being insidious. They had also affected seriously property, agriculture and animal husbandry. He mentioned deaths from beryllium compounds; the etching of windows by hydrofluoric acid, the toxic effects of the fumes of various metals on human beings and of fluoride on crops and cattle.

They should not have to take action to prevent those things happening. They should not be permitted. Factory legislation should be extended by requiring that where in the interests of the workers it was necessary to remove from the environment of the worker any noxious fume, toxic vapour or dust, those substances should be removed or rendered innocuous before discharge to the external atmosphere.

W. Bate (C.P.H.I., Wallasey) referred to the mention in Mr. Don's paper of the idea of a single purpose smoke authority for " metropolitan " areas. He suspected that Mr. Don feared that such an authority might easily come into being in the event of local authorities failing to implement the Clean Air Act, and particularly its provisions relating to the making of smoke control areas on a grand scale. The Beaver Committee had said that clean air could be achieved in fifteen years, but already even enthusiasts for that work were thinking in terms of twenty to twenty-five years. A speaker at a recent conference had estimated that it would cost about seven to ten thousand pounds a year to secure clean air in a town of about fifty thousand within twenty to twenty-five years. Mr. Bate asked whether local authorities were so serious about the Clean Air Act as to be prepared to spend that kind of money. He suggested that local government would not appear to be taking the work seriously until town after town had produced development plans to secure the progressive cleaning of the air of entire towns within that period, and he asked local authority representatives present to see that their local health services received their proper share of the finances at the disposal of the local authority.

Councillor D. Raper (Romford) said that he wished to refer to a point which had been made in both papers on the theme of co-operation.

He drew attention first to the reference made by Mr. Don to the anomalous position of a Civil Servant keeping watch on one smoke stack, and a Local Government Officer on the next. In his opinion such a situation could not merely, as Mr. Don put it " scarcely hope to escape criticism," but indeed invited criticism. He felt that the relationship between the Alkali Inspector and the Public Health Inspector should be analagous to that between the Public Analyst and the Public Health Inspector in Food Hygiene matters. The vast majority of these questions were dealt with by the Public Health Inspector in the normal course of his duties, only the exceptional cases being referred to the Public Analyst for his opinion and advice. There was no reason why a similar procedure could not be adopted by Public Health Inspectors and the Alkali Inspector in relation to air pollution problems. In any case it was inconceivable that adequate supervision of the thousands of factories in the Scheduled Industries could be afforded by an Inspectorate whose qualified personnel could be counted on the fingers of both hands. He endorsed the remarks of an earlier speaker on the all too frequent practice of removing noxious and toxic fumes from the environment of industrial workers only to discharge them into the atmosphere to the annoyance and danger to health of the neighbourhood.

Councillor Raper then referred to the examples given, in Mr. Lindsay Taylor's paper, of co-operation between neighbouring local authorities and in particular to consultations going on between local authorities in the south-east London area. Romford, which he represented, had only a relatively small number of factories and although atmospheric pollution by factories did exist, it was by no means a major problem. The main problem so far as Romford was concerned, arose from its position on the north-eastern outskirts of the Metropolis. This resulted in a high proportion of the " outfall " from London being borne down upon it on the prevailing south-west winds. He could see very good reason, therefore, for co-operation between local authorities in and around north-east London to consider the question of creating smoke control areas generally rather than for each local authority to act entirely on its own.

H. E. T. Lowbridge (C.P.H.I., Willenhall), said that emphasis had been given to the availability of smokeless fuel but he wished to stress the importance of the proper type of grate.

Most people were aware that approved types of grates had been installed for a number of years and there was a natural belief in the minds of people that those appliances would burn smokeless fuel. He mentioned an instance where a rather expensive approved type of grate had recently been installed and it was found that, whilst it would burn coal satisfactorily, it was not satisfactory in the burning of domestic coke. The firebars had been replaced with ones having wider spacing and then coke had been burnt satisfactorily.

It was known, and in fact British Standard Specification 2845 required, that the spacing of the bars of the bottom grate should be $\frac{5}{8}$ in. He suggested that officials responsible for the provision and supervision of installation of approved appliances should see that the spacing between firebars was satisfactory otherwise local authorities would probably be faced with the replacement of firebars when the houses in which they were installed were included in future smoke control areas.

Arnold Marsh (Director, N.S.A.S.) in a written comment states that the report he had prepared on the Availability of Smokeless Fuels raised only a few remarks in the discussion that called for reply. He agreed with Mr. Lowbridge about the importance of the correct type of grate, and hoped that local authority officials would make a note of Mr. Lowbridge's advice. He also thanked Mr. McGlashen for amplifying his necessarily brief reference to the importance of off-peak loads in the development of space heating by electricity.

Parts of Councillor Piddington's contribution were very controversial, and regrets had been expressed to the Society since the conference that he should have questioned the sincerity of those who are known to be seeking to develop a fuel policy that inevitably contains many difficult, and possibly intractable, elements. It has seemed desirable to allow the Board concerned with the manufacture of " Cleanglow " to make a reply to Councillor Piddington's criticisms.

On price it was pointed out that " Cleanglow " is made from specially selected washed coals brought by rail from the Midlands, and from which approximately ten therms less of gas is obtained. These factors and heavy freight charges make it impossible for " Cleanglow " to be sold at the same price per ton as that for coke. The maximum retail price has been approved by the Ministry of Power, and like all other solid fuels, only after close examination. The maximum permitted prices are available to the public at all local fuel overseer's offices.

" It is not easy to follow Councillor Piddington's arithmetic when he refers to the additional cost of 'Cleanglow' as being 25s. 10d. per ton and 2s. 7d. per cwt. In point of fact, the additional cost of 'Cleanglow' compared with coke is approximately 30s. per ton or 1s. 4d. per cwt. in the small cwt. delivery range."

On distribution it was said that " when the Board decided to manufacture 'Cleanglow' in quantity, the method of equitable distribution throughout the Board's coke supply area was fully considered. As 'Cleanglow' was to be made only at Ascot and Lea Bridge works, the Board could not, on economic grounds, undertake the delivery of small quantities from the two centres of production. It was therefore decided to market this new fuel solely through the Board's authorized distributors, which thereupon made available approximately 1,000 additional centres of distribution throughout the area."

Industry and the Clean Air Act

HOW INDUSTRY VIEWS THE CLEAN AIR ACT

By

Leslie A. W. Jenkins*

The passing of the Clean Air Act was an event of very great importance and its application will have far-reaching effects in the economic and social life of the country.

It has been generally recognized that the emission of smoke and grit from domestic as well as industrial appliances constitutes not only a public nuisance causing substantial damage to health, buildings and plants, but is also a source of considerable fuel wastage. I am certain that very few industrialists will not share my conviction that a practical interpretation of the Clean Air Act can be a great step forward towards a better state of health of the community and a cleaner and brighter appearance of our industrial towns.

Consequently we wholeheartedly support the intentions of the Act and wish to implement its requirements as speedily as possible.

The problem, however, is not as simple as it at first appears.

It would perhaps be of interest to point out the chief sources of air pollution and the relative proportion of smoke to grit and dust.

It has been estimated that in 1955 the amount of coal used for domestic purposes was 38 million tons, and for industrial purposes 67 million tons. The weight of pollutants discharged into the atmosphere was: from domestic appliances 900,000 tons of smoke and 100,000 tons of grit and dust; from industry 800,000 tons of smoke and 300,000 tons of grit and dust.†

Approximately two million tons of coal per annum are therefore discharged to the atmosphere either as smoke or unburned carbon in grit.

As far as the emission of dark smoke is concerned the domestic fire is by far the worst offender of the two, especially as the discharge occurs at a low level, but industry is largely responsible for grit and dust emission.

In this paper I wish to consider some aspects of the Act as it affects industry because the Clean Air Act forbids the emission of dark smoke except for short specific periods and demands that grit and dust should be reduced by fitting efficient grit arrestors.

Although the provisions of the Act are not rigid, their application to industry raises two main problems:

(1) What technical improvements are necessary to make the operation of the plant conform with the Act, and

(2) How these improvements can be introduced at an economical price and without undue interference with the work of the plant.

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† From Paper by Sir Ewart Smith at the Conf. of Mech. Eng. on Clean Air.

The first problem is purely technical whilst the second is a matter of careful study of the economics of the required technical improvements.

The realization that smoke emission is a sign of gross inefficiency is growing steadily and the Act in this respect can indirectly play an enormous part in raising the overall efficiency of fuel usage. Thus if industrial management will look upon the Act as a means of achieving higher plant efficiencies the implementation of its requirements will be doubly beneficial.

On the other hand, the local authorities must realize that there may be considerable difficulties of a technical or financial nature in effecting a major improvement, and therefore they should exercise patience and understanding.

A great deal of research in Fuel Technology has been carried out in recent years and much has been learned about the various factors affecting combustion of fuel in industrial boilers and furnaces, so that we know now that given proper appliances and suitable fuel we can achieve if not perfect combustion, almost certainly smoke-free operation.

In fact there would probably be no need for the smoke-emission part of the Act if an adequate supply of low volatile coal was available. However as supplies are, while theoretically it should be possible to design industrial equipment suitable for a wide range of coals and to operate it without emission of smoke or grit, the problem we have to face is how to burn coal of all types and grades in a variety of appliances under different, and at times, difficult conditions.

While it is believed that new boilers or furnaces will incorporate " Clean Air features," at present our concern is how to deal with existing plants, some of which have been in operation for half a century and are likely to be offenders.

Currently the problem of smoke emission in industry falls into three categories:

(1) easily curable,
(2) partly curable, and
(3) incurable.

I wish to stress that this view is not contrary to the expectations of the Act, but for the next few years some industries in spite of honest efforts, will not be able to comply with the Act until radical modernization of operation is carried out.

In the first category, the equipment and the fuel are suitable for smokeless combustion. Due to maladjustment of operating conditions, however, dark smoke is emitted. This state can easily be remedied by calling in an expert to diagnose the trouble and to advise on improvements.

The second category concerns hand fired boilers of which there still is a very large number in this country. With many fuels it is virtually impossible to avoid, at all times, the emission of dark smoke. In general, however, this is largely, but not entirely, in the hands of the stoker; if he has no knowledge or understanding of the principles of combustion, the results can be deplorable. Not only may there be excessive smoke emission but also great heat losses.

To offset the human error there is and should be a general trend in industry to convert boilers from hand to mechanical firing but during the transition period, it is to be hoped that tolerance will be shown by the local authorities.

It has been estimated that there are, in this country, about 40,000 hand fired boilers which will in time be converted to mechanical firing, at a total cost of £40,000,000.

This task may seem formidable, but it has been tackled boldly by industry and the rate of conversion is steadily increasing.

It should be remembered that mechanical firing is capable of raising the overall efficiency of a boiler by approximately 8 per cent above that achieved by good hand fired practice. This, however, is rare, and if it were widely known that savings up to 15 per cent are possible, dependent, of course, on the original efficiency of the hand firing, it would stimulate the rate of conversion in the knowledge that the capital expenditure will soon give a good return through the saving in fuel.

Out of the 67 million tons of coal used in industry, probably 20 million tons are burned in hand fired boilers. If converted to mechanical firing, the saving would amount to about two million tons of coal or approximately £10,000,000 per year, thus the cost of conversion would be recovered in about four years.

While Sir Ewart Smith's figure of total industrial coal consumption with its resultant air pollution has been quoted, it should be emphasized that only some 40·7 million tons was directly attributable to the three sections into which manufacturing industry, as distinct, for example, from collieries, is divided, namely, iron and steel, engineering and metal trades, and other industry.

Coal consumption for domestic purposes was therefore only slightly less than that of the three groups controlled, in the main, by private industry. Thus Sir Ewart's analysis of air pollution shows manufacturing industry in a favourable light in comparison with domestic purposes, and points clearly in what direction the most effort will have to be directed if the Act is to be fully effective. Nor is it to be implied that manufacturing industry is responsible for using the greater proportion of hand fired boilers; in fact, a large number of these are still in use at collieries though the Coal Board are fast replacing them.

The local authorities (inspectors) can play, indirectly, a very important part in saving fuel. I would suggest that, at least in the early stages of implementation of the Act it is not enough to draw the attention of management to the fact that their plant is offending the Clean Air regulations. It would be most desirable and indeed generally appreciated if an inspector, by his tactful and friendly approach, tried to help management by suggesting and encouraging them to get the advice of combustion experts.

It is important that the industrialist knows that most of his smoke and dust troubles can be cured, in the majority of cases at reasonable expense and that he can be financially assisted by the Government if the necessary alterations lead to fuel savings, which in nearly all cases they do.

The Government Loan Scheme for Fuel Saving Appliances has been in operation since June, 1952, and so far the value of the loans granted exceeds £4,000,000.

Loans are available for most kinds of fuel saving schemes including mechanical stokers, improvement of draught systems and other equipment, so long as the expected savings are reasonably substantial and they would not otherwise be achieved.

Repayment of a loan is spread over an agreed period depending on the financial savings to be expected and on the life of the plant, subject to a maximum of twenty years. The loans are free of interest for the first two years after the equipment has been installed, thereafter commercial rates of interest are charged.

In the operation of this scheme, N.I.F.E.S. acts as technical adviser to the Ministry of Power, but takes no part in the subsequent financial consideration as to whether a loan should be granted.

Not all industrialists who are eligible for the loan know about it and it would be a very good thing if the Smoke Inspectors made themselves familiar with the Loan Scheme so that they can apply this knowledge when they come across a suitable case.

The third category covers processes where smokeless combustion is virtually impossible and unless new methods are devised it will be extremely difficult to comply with the Act.

To give an example I have in mind the ceramic industry which uses about 3·5 million tons of coal a year as well as considerable quantities of liquid and gaseous fuel and electricity.

Of the two types of kiln, the Continuous is the more efficient one and less troublesome from the combustion viewpoint but the Intermittent type is still widely used in some branches of industry because it is better suited to the firing requirements of some products. In fact, the Intermittent kiln is considered essential in the firing of so-called " blue " products, large size blocks and a few other ceramic articles. " Blue " refractory requires a reducing atmosphere, a condition conducive to smoke emission. This is achieved by heavy feeding and exclusion of secondary air. It is difficult to see how the smoke emission can be overcome short of doing away with the process itself. This is perhaps a special case though the quantity of coal involved and therefore the extent of possible smoke emission is considerable. From information supplied by experts in the ceramic field we know that all Intermittent kilns are likely to emit smoke at certain periods in the firing cycle. Although improved kiln design and the wider use of mechanical stokers can do a great deal to mitigate smoke nuisance, compliance with the Act may prove to be difficult.

As I have already mentioned, in order to avoid smoke emission, in all cases, the coal to be used must be suitable for the appliance in which it is to be burnt or, as it happens in practice, the appliance is designed or chosen to suit the type of coal readily available. This does not always work because of the shortage of solid fuel and the necessity to use all types of coal. It is obviously easier to use graded coal than smalls, but it would be inconceivable from the national as well as the individual economy point of view to avoid using fines and smalls in bulk since they constitute 40 per cent. of the output of our mines. In this connection, I should like to quote from an Open Letter written by Mr. S. B. Cole, the Chairman of the National Horticultural Pottery Manufacturers Association to Mr. Gerald Nabarro, M.P., and published in the *British Manufacturer*. Cole writes:

" My own deliveries of " cobbles " contain an average of 10 per cent. of almost unusable smalls, unusable that is for the kilns for which I purchase it, but I am able fortunately to dispose of it on boilers, with coke. This however is impossible without causing some smoke and if I and others similarly placed are to eliminate all smoke something will have to be arranged about this small coal. We cannot throw it away. The Coal Board say we must use it. Even well screened coal at pit head becomes much reduced to small and/or dust in handling on its travels to the consumer. Grabs, tipping, etc., help the process. In view of the vast tonnage of this stuff which the Coal Board must dispose of, and which must create smoke when used in bulk, something must be done about it before smoke abatement can become realistic."

He then goes on to say that if plants would avoid using inferior grades of coal or fines some coal fields would have to curtail output or even close.

It is obviously most essential to use every bit of coal and we have learned how to use low grade coal with good results. The main trouble arises when one is compelled, for economic reasons, to burn graded coal mixed with smalls and fines.

In the same letter, Cole mentions a case where two down-draught kilns which were converted to gas in accordance with the general trend, have been reconverted to coal because of the large increase in the price of gas, which made their operation uneconomical. This may not be typical but is sufficiently important to show that in spite of a genuine effort, the project had to be abandoned for economic reasons. This was a case of either closing down or running the kilns on coal at the risk of occasional smoke emission.

The Clean Air Act also requires industrialists to reduce the emission of grit and dust. That this will present some difficulty in the present state of development to many branches of heavy industry, such as iron, steel and cement, has been recognized in the Clean Air Act which relates requirements, in such instances, to current state of knowledge, and it may be some years before the desired standard is reached.

In general industry however and where only solid fuel of conventional type is burnt the emission of grit and dust is from the boiler plants and its reduction to reasonable proportions does not present the same measure of difficulty. Considerable reduction in grit emission can be attained by proper attention to combustion conditions, including the provision of suitable equipment for the fuel which is being supplied. Reduction in this manner will, as with smoke emission, lead to increased boiler efficiency and so pay dividends in hard cash.

In many cases however, particularly where low grade fuel is being burnt, with a high proportion of fines, combustion control will not be sufficient and it will be necessary to install grit arrestors to trap the grit which would otherwise pass up the chimney.

The magnitude of necessary expenditure on grit arrestors is given in Sir Ewart Smith's paper from which the following passage is quoted:

> " It is estimated that medium efficiency cyclones will become necessary in respect of a consumption of 20 million tons per year of coal by industry working one shift per day. The corresponding cost will be approximately £40 million. In addition, much more expensive electrostatic precipitators may ultimately have to be installed in larger installations (burning about 30 million tons of coal per year) including boilers, metallurgical and cement plants, etc., on continuous shift. The corresponding cost will be approximately £60 million."

Some plants will require higher chimneys for effluents from combustion and other processes and the total cost of erection has been estimated by the same author to be £50 million.

Incidentally, it is to be hoped that Local Authorities will pay due regard to all the circumstances where the height of chimneys is considered. Although the Beaver Report (Appendix VI) suggests that 120 ft. is necessary for low buildings, it states that discretion must be exercised for small installations. In total, however, a sum in the neighbourhood of £150 million may well have to be envisaged by industry to cope with the problem of grit and dust, a very heavy expenditure, but quite inevitable if the Clean Air Act is to be implemented.

It is unfortunate and a lack of incentive to Industry that no return for this expenditure in the way of fuel saving can be balanced against the cost.

The knowledge that the provision of grit arrestors, where necessary, can provide a direct contribution to industrial productivity since the presence of grit in the atmosphere can have a very deleterious effect on the production of machine parts, or food preparation, to say nothing of laundries, is not likely to appeal to the already tax burdened and expense-conscious industrialist.

Herein lies the main difficulty as while the Act insofar as it makes for better combustion conditions brings its own rewards in saving, enforced capital expenditure with no direct return, if not dealt with under the Act in a spirit of understanding and sympathy, can have grave repercussions, particularly amongst smaller industries and firms already meeting severe difficulties through foreign competition. Many firms also are obliged for practical or economic reasons to dispose of their waste or by-products in the boiler house not only as a means of disposal but as a contribution to alleviating their fuel bill. With certain material this adds to dust and grit problems which even if technically surmountable might involve capital expenditure which could not be offset or justified by the fuel value of burning such by-products. The waste disposal section of the local authorities might have a very severe problem on their hands if such pressure were put on an industrialist that he put the waste by-products for refuse collection rather than utilize them as at present as a contribution towards fuel saving.

However, to sum up, the Clean Air Act throws a definite responsibility on industrialists to reduce the present pollution of the atmosphere by dust, smoke and grit. Despite the difficulties outlined, and providing sufficient time and patience is exercised in the main for financial reasons, they will when properly met, lead to higher efficiency and better fuel economy.

It is a fact that in the majority of cases the problems of smoke emission in general industry can be solved by relatively small alterations and improved operation of the boiler plant, and in view of the financial savings accruing to the industrialists it should not have been necessary, apart from its wider aspect, to pass an Act to stimulate him to save the country's most precious asset.

In this connection, I should like to relate my own experience with a smoke emission problem in our Avon Wharf works, a factory producing veneers.

Two boilers, a Lancashire with a chain grate stoker and a Paxman Economic supply steam to the works, the flue gases being exhausted by the induced draught fan into a 75 ft. brick chimney. The Paxman Economic is hand fired using wood waste burnt in a Dutch Oven.

The fuel used consists of off-cuts from logs, veneer sheets, shavings from planing machines, sawmill dust and other wood waste. The bulk of this material is of high moisture content and causes no combustion troubles but, rather surprisingly, off-cuts and waste of dry veneer cause dark smoke in the first stages of combustion.

We could not afford not to use this material, especially when owing to a modified trimming process, the volume of dry waste was increasing. As there seemed to us to be no solution of the problem, we contacted the National Industrial Fuel Efficiency Service to obtain their expert advice. A visit of their Engineer was arranged and as a result of his investigation, a number of technical faults, which were not apparent to us, were put right and proper combustion control was introduced.

The proportion of volatile matter in wood is much higher than in coal thus requiring more secondary air for combustion. By rigidly controlling the feed of wood waste and supplying the right proportion of secondary air, considerable improvement in combustion conditions was obtained.

As this obviously required the services of a trained stoker, a suitable certificated man was found for the job. In addition we signed a Regular Service Agreement with N.I.F.E.S. I am glad to say that we are now running the boilers at a considerably higher efficiency so that as a natural consequence, smoke emission is reduced to reasonable limits for most of the 24 hours.

I should like to mention two typical cases where problems of smoke emission and poor boiler performance have been very successfully solved.

Moss Brothers (Hebden Bridge) Ltd., wished to eliminate smoke emission and to improve the performance of their two Lancashire boilers. Examination of the boiler house revealed that a few mechanical alterations were required, and those were carried out at a total cost of £250. The improved operation produced a saving of five tons of coal per week. The smoke trouble disappeared completely.

Castle Rubber Works Ltd., Warrington, asked for advice about smoke emission. Inspection showed that two Lancashire boilers were being used at less than 50 per cent. rating and that the draught was poor. Air inleakage was taking place through the brick settings and the dampers of an obsolete soot-blowing plant were fully open. An incinerator smoke pipe led into the soot chamber, causing loss of draught on the boilers. Appropriate recommendations, which were implemented by the firm, have enabled the load to be carried on one boiler. The boiler fireman enrolled in a N.I.F.E.S. Boiler Operators' Course. Fuel consumption has now dropped from 40 to 35 tons a week, despite an increase in production and smoke emission has been overcome.

Many more specific cases could be mentioned where the main trouble was smoke emission and by solving this problem, substantial fuel savings were brought about.

In the times in which we live I

recommend to those of my fellow industrialists who may have similar problems the pleasing, and certainly unusual, experience of obeying authority and saving money at the same time.

I think that it can be said that the responsible industrialist, and that covers the vast majority of those much exhorted and harassed mainstays of the country's economy, is only too willing to do everything to bring the Clean Air Act to full realization provided that its requirements can be carried out within economic limits. Provided also help is given in its administration by guiding him on what to do and, where there is ignorance, bringing attention to the benefits he himself will reap in fuel efficiency. I do not think the vast majority today would plead for those few who refuse to co-operate or take advice and continue in their stubborn ignorance to adhere to outdated methods and waste fuel. It is a sad reflection that through bad boiler house practice a stoker can waste more coal in a day than a miner can dig.

In conclusion, I think the industrialist would sum up by saying that on his side he will do his best but if it is to be done quickly and willingly, he might well ask that those who have to administer the law might well have as their charter the following five points:

(1) Tolerance, courtesy and an appreciation of genuine difficulties especially if they are economic.

(2) Knowledge and uniformity of judgment as a basis of selection for inspectors.

(3) The recognition that what management may plan an ill-informed or ill-intentioned employee can defeat.

(4) By-products can be as much of a clearance problem as a smoke nuisance.

(5) And finally, the industrialist by his position is the easier scapegoat for any Government measure. On the evidence he is neither the worst nor the largest offender in air pollution and his own efforts will all the more willingly be carried out if he sees the Nationalized Industries and the general public contributing on an equal basis to the common good.

FUEL EFFICIENCY AND CLEAN AIR

by

Angus Macfarlane, Ph.D.

Chief Executive, National Industrial Fuel Efficiency Service

As a nation, we tend to a stoical acceptance of a situation once established, even if it is one which we find unpleasant. Often it may not be difficult to find a remedy; yet little is done until a Dunkirk situation arises. Atmospheric pollution can be cited as a typical example. It is certainly no new situation brought about by modern conditions. Its existence has been recognized for centuries and attention drawn to the danger to health, the damage to buildings, the hindrance to trade, industry and agriculture, and the immense cost to the nation which it caused. In fact, we knew very well what was happening but seemed to take a perverse pride in our dirt and grime, even when grumbling about it. Only when the disastrous London " smog " of 1952 cost 4,000 lives did we decide that air pollution must be eliminated.

Indifference to fuel efficiency has run parallel to indifference to atmospheric pollution. We have been called " the champion fuel-wasters of Europe," and seem to have rather gloried in the title. Perhaps the indifferent ear heard only the first half of the title—" champion "—and was deaf to the character of the " championship." Again, the well-established principle that " where there's muck, there's money," has been an effective barrier to the fuel efficiency campaign as well as to smoke abatement.

Of course if one sets out to overturn so firm a principle as " where there's muck, there's money," one has to be sure of one's ground! In the past, neglect of fuel efficiency may to some extent have been justifiable economically. Before the war, coal in this country was cheap and abundant. The change from that pre-war condition of a national energy surplus to the present " energy gap " has been a very rapid one. On the other hand, the boiler plant or the furnace is a robust piece of equipment with a long life. Hence we are firing today furnaces and boilers made in 1925—sometimes those made before 1900—with coal or oil at 1957 prices. A revaluation is essential, but it is not perhaps surprising that all industrialists, preoccupied as they have been since the war with so many problems on the production side, have not rushed to undertake it.

I do not wish to dwell on the discouraging past, however, for my main purpose in this address is to report a real and encouraging change. N.I.F.E.S. was created 3½ years ago in the belief that a new approach to the problem of inefficiency in the industrial use of fuel was essential. You are meeting this year to plan a new approach to atmospheric pollution. What success we have had may be of direct concern to you.

It is true that your approach and ours come from different backgrounds. You have to administer a new statute —the Clean Air Act. We have no statutory background whatever; N.I.F.E.S. must approach the industrialist on the basis that it is to his interest—as well as the nation's—to use his fuel efficiently. But I daresay that in fact you will find persuasion an important factor in reaching your objective. At any rate, it may be of value to you to know that the industrialist is today more ready to listen to advice on his fuel problems than at any time in the past. Almost every improvement in fuel efficiency is a contribution to cleaner air.

Let me then give you a brief survey of the methods by which N.I.F.E.S.

advises industry. Assuming that one starts with a works where no particular attention has previously been paid to fuel efficiency, the problem falls into four parts:

1. (1) Finding out accurately where heat is being wasted, and what is needed to put the plant in order.
2. (2) Providing an after-service to ensure that the adjustments are made, and that the improved efficiency is maintained.
3. (3) Being available to advise on any fresh problem that arises at a later date.
4. (4) Helping in the training of the firm's staff who are concerned with fuel utilization, whether as works engineers or boilerhouse operators.

Heat and Power Surveys

Our code name for the first of these services is the Heat and Power Survey. For such a survey, N.I.F.E.S. will provide all the instruments required to draw up a detailed heat balance, not only of the boiler plant but of the whole works. The survey can thus cover the use of steam for process, power plant, space heating, and so on. The emphasis of N.I.F.E.S. work is, indeed, increasingly on the utilization of steam for power and process, because it is there that the biggest savings can be made. But since your interest is primarily in combustion, I shall concentrate on that side of our work.

With the instruments on a N.I.F.E.S. survey, comes the team of N.I.F.E.S. engineers. Of course, their first job is to take the measurements that will lead to the report on the efficiency plant, the fuel savings that can be made, and the plant additions that can be justified economically. Their objective, however, is not just to leave the industrialist with a lot of paper proving what a mess he is in. While they are on the site they will, in co-operation with the firm's own engineers, make all the operational improvements that they can.

A Heat and Power Survey, therefore, is not simply an analysis of how efficiency can be improved. It is an exercise in putting the improvements into practice, so that at the end, the plant is working under the best conditions then attainable. During the last year, Heat and Power Survey reports have been provided to 548 firms. In 434 of them, it is possible to assess the fuel savings directly. They amount to 222,500 tons per annum or 18·4 per cent. of total consumption.

A Heat and Power Survey may range from a simple boiler test requiring the work of two N.I.F.E.S.' engineers for two or three days, to a comprehensive investigation occupying a team of a dozen for several weeks on end. The average survey during 1956-7 took 23 engineer days. Whatever the length of time, you will, I am sure, appreciate that follow-up action is essential. It is one of the intractable characteristics of the fuel efficiency problem—as of the atmospheric pollution problem—that continued effort is necessary to maintain improvements once made.

Regular Service Agreements

This is the reason for the second line of approach, the provision by N.I.F.E.S. of an after-service, under a Regular Service Agreement. A series of regular visits by an engineer, arranged to suit the firm's requirements and convenience, enable him to check on operating standards and provide an opportunity for the staff to discuss with a specialist any problem that arises. The engineer is eventually regarded as an additional member of the staff and his advice becomes increasingly valuable as he becomes familiar with the firm's operating problems. If detailed investigation becomes necessary, his knowledge of the plant and experience of working conditions make it possible to carry out the test work more rapidly and surely. This service, brought into operation some two years ago, proved from the outset to be one of the most popular offered by N.I.F.E.S. The number of agreements rose from 262 in 1955-6 to 426 in 1956-7, and there was an increase of 86 per cent. in the engineering time given to this work.

The scheme has appealed as strongly to local authorities as to industrialists. Their bills for fuel are substantial, but consumption is divided among many buildings scattered over a wide area. Thus the authority's hard-pressed engineering staff is presented with a difficult problem of control, often intensified where boiler operation is a part-time occupation of staff with other duties.

The Shropshire County Council and the Corporations of Manchester, Southampton and Derby were among the first to enter into Regular Service Agreements with N.I.F.E.S. I am happy to say that the Corporation of Hastings is also among our clients. In the autumn of 1955, the movement was greatly stimulated by circulars from the Ministry of Education and the Scottish Education Department, urging greater attention to fuel consumption in schools, and the number of local authorities served has now reached a total of over 80. Some of the agreements have run through two successive winters, so that the results are becoming apparent. Yet it is difficult to give them quantitatively, first because the fuel is required mainly for space-heating which is so dependent on the severity of the winter, second because the consumption in a single school is not large and is difficult to check. Nevertheless, it has sometimes been possible to assess the economies accurately; for example, in 15 schools in the Eastern Counties the total savings amounted to 11½ tons a week. Much of the savings in schools results from the lectures and practical demonstrations to the school caretaker responsible for the heating plant. Talks to the teaching staff about the proper control of classroom heating have also had a good effect. The most lively sessions have been those attended by both headmasters and caretakers; the cross-fire of discussion has made the central heating system temporarily unnecessary.

In other areas, the schools are being tackled according to a long-term plan. In the South-West, arrangements have been made with several education authorities to visit 20-30 schools twice during the year. At the first visit, made during the heating season, the object is to determine the efficiency with which the plant is working and to instruct the boiler operator in correct firing practice. At the same time, the balance of the heating system is checked, because it is so often found that one block of classrooms is overheated while everyone in another part of the school is freezing. After the heating season is over, the second visit is paid to make a thorough inspection for the need for repairs and maintenance. Most of the recommendations have been acted upon promptly by the local authorities, so that by the time heating is again required the benefits are secured. The result has been not only to save fuel, but often to provide a satisfactory standard of heating where previously one was lacking.

Extensive programmes of work have also been carried out at schools and local government buildings in the North-Eastern Area. Here, some 500 visits have been made to assess the efficiency of boilers and heating systems. Practical instruction has been given to men operating the plant, and short two-day courses have been given to 150 men. In general, the findings were that boiler efficiencies could be increased by preventing air leaks, better lagging, the cleaning of heat transfer surfaces and improved firing. The condition of heating systems varied, but many suffered from scaling of pipework and radiators, air-locks and inadequate boiler plant. Once again, it is not possible to give a firm figure for the savings made, but it is reasonably certain that an average of at least 5 per cent. will be achieved.

Another recent development has been a Regular Service Agreement signed with the Worcestershire County Council. This will extend over three years, and will cover the practical control of all the Council's premises. The fuel bill is in the region of £200,000 on fuel for central heating boilers. The first target is to reduce that expenditure by 10 per cent., and when that has been done an attempt will be made to achieve a similar saving on the remainder of the fuel bill.

Specific Advisory Service

Third, it has been found that, since the fuel situation is ever-changing, N.I.F.E.S. engineers must be available to its industrial clients to advise on specific problems as they crop up. During the last year, it has become apparent that there are firms requiring information which, though not needing a lengthy examination or an instrumented survey, do require a high standard of technical experience to answer. Sometimes these problems arise while the recommendations of a N.I.F.E.S. survey are being implemented; other enquiries come from firms which have decided to improve their efficiency and are anxious to obtain an outside opinion on plans which their own staff have developed. To meet this need, a Specific Advisory Service was introduced in June, 1956, and it rapidly gained popularity with industry. By the end of March this year 464 firms had been visited under this service and advice had been given on the abatement of smoke and grit, the insulation and space heating of buildings, the correct operation of existing plant, the burning of waste products, flash steam recovery and the choice of new boiler plant. Other consumers asked for checks of combustion efficiency, confirmation of their own engineers' calculations of heat losses, or of their assessment of how best to meet the increased heat requirements needed if production is increased or the factory extended.

Education and Training

Fourth, there is a great need for imparting up-to-date information to those in industry on developments in the use of fuel. In collaboration with the Regional Councils for Further Education, N.I.F.E.S. has conducted a number of residential refresher courses for works engineers at several centres throughout the country. It runs regularly, at its Reading office, one-week courses on the use of fuel oil, both for engineers in industry and for members of the staffs of fuel distributors. Special courses or lectures for individual firms and organizations are also popular, but N.I.F.E.S. courses in the training of boiler operators are probably of more interest to this audience.

Of the three main causes of smoke emission from an industrial boiler plant:

(1) bad maintenance of plant;
(2) use of fuel which is unsuitable;
(3) inefficient operation on the part of the operators,

the third is that most frequently responsible. To overcome it, we must, in my view, first eliminate the manual labour of stoking by mechanization wherever possible, and second, ensure that the operator knows the principles of combustion and understands how his plant works.

This is an uphill task. It has been estimated that there are 75,000 boiler operators employed in this country, though no one seems to know the number at all accurately. Many of these are part-time stokers, combining this duty perhaps with that of caretaker in a large commercial building or a school. As already mentioned, an important part of N.I.F.E.S. Regular Service Agreements with local authorities is directed to the training of these men.

The full-time boiler operator needs more knowledge, and we should not rest content until he has taken the Boiler Operators' Certificate of the City and Guilds Institute. Admirable training has been available for years at many technical colleges, but has proved of limited appeal chiefly because of the difficulties associated with shift work and travelling.

N.I.F.E.S. contribution has been to offer a supplementary system of training, based on the example of the National Coal Board. Under this system, the course is taken to the man; the boiler operator is not asked to go back to school. He is provided with material which he could study in his own home and by supplementing this with practical instruction by a N.I.F.E.S. engineer on his own, or similar, boiler plant. Both men and employers were required to play their part; the men to give up some of their leisure to study, and the employers to allow the eight days of practical training during the 21 weeks of the course as time off without loss of wages. Experience has shown that co-operation on both sides is excellent. Many firms have not only enrolled their men for training, but have acted as " hosts " to courses, welcoming the students and instructors most hospitably.

The scheme started, therefore, with the advantage of being designed to meet the needs of the group of men it wished to attract and with a plan which would fit their working conditions; special arrangements are made, for instance, to meet the requirements of shift workers. Over 2,000 have enrolled since the scheme came into operation two years ago. But the way to judge the success of any course is to assess the wastage which always occurs as students lose interest, and in this case 95 per cent. of those enrolling complete it. This is also a fair indication that, despite their varying ages and educational background, practically all the men are able to absorb theoretical knowledge, a point which raised some doubts at the beginning. Of those who sit for the City and Guilds examination, for which all the necessary arrangements are made on their behalf by N.I.F.E.S. over 80 per cent. are successful.

The essence of the course is simplicity of presentation and an informal approach by the instructor when putting over the theory of combustion to men who, for the most part, have hitherto regarded their work as practical only. This side is not neglected, however, for the instructors are experienced stokers, chosen for their work because of their extensive knowledge of various types of fuel, plant and boilerhouse practice. Part of the time at on-site meetings is devoted to discussion of the problems which the men meet daily in their jobs; this establishes a feeling of confidence which goes a long way towards the success of the course. One of the most encouraging features has been the keenness with which the men have responded to tuition. Some felt doubt at first, but enthusiasm rose as training progressed. Firms have reported that as their men acquired a thorough knowledge of the subject and applied it to their work, noticeable savings in fuel resulted. It is obvious, therefore, that there is no lack of interest on the part of the men once training facilities are made available in a form which is acceptable to them.

Results of N.I.F.E.S. Work

That is a brief outline of the methods developed by N.I.F.E.S. in its first three years to serve the fuel user. There is nothing final in the methods; we expect they will change with circumstances, as well as grow in their application to more clients.

The increasing demand by industrial and other users of fuel for N.I.F.E.S. services is best summarized by the statistics for the three years of operation, shown in Table I, on next page.

This is an encouraging record of increasing interest by industry in the way it is using its fuel. Do not imagine that we in N.I.F.E.S. take credit for the results; we are well aware that rising prices, shortages and Suez are the main reasons for the change. But we hope and expect that the record of savings which so many firms have achieved will attract even greater numbers to follow their example.

N.I.F.E.S. and the Clean Air Act

One of the major grounds for optimism is the passage of the Clean Air Act. In the past, many calls for N.I.F.E.S. advice have arisen from firms with problems of smoke or grit emission. They have often been prepared to proceed from the solution of the immediate problem to a general review of their fuel usage, and reaped a substantial financial gain as a result. For these opportunities we have

	Year ending 31st March, 1955 (11 months)	Year ending 31st March, 1956	Year ending 31st March, 1957
Visits to factories, etc. for all services	8,808	12,509	13,493
Clients provided with:			
Heat and Power Surveys	327	495	517
Regular Service Agreements	78	262	426
Specific Advisory Service	—	—	464
Boiler Operators Trained	—	708	1,120
Engineering Staff of N.I.F.E.S.	151	195	205
Earnings	£18,600	£55,800	£105,341

Table I

generally been indebted to the Public Health Inspectors who, considering that the pollution problem could not be solved by the firms' own staff, have advised them to bring in N.I.F.E.S.

Implementation of the Clean Air Act will obviously bring greater opportunities for collaboration. It has already been responsible for two new developments; one has been the demand for lectures on technical problems likely to be encountered by Public Health Inspectors in connection with this work. Last winter in Glasgow and Durham, two series of lectures were given to 72 Public Health Inspectors, whilst in Cardiff a series of twelve lectures was given to men studying at the College of Technology and Commerce for the Smoke Inspector's Certificate. We should welcome the extension to other areas if the demand arises.

The other arises from the provision in Sections 3 and 6 of the Act for prior approval by local authorities of specifications for new furnaces and grit-arresting plant. The Ministry of Housing and Local Government and the Department of Health for Scotland have suggested to local authorities that they may wish to take advantage of the experience of N.I.F.E.S. engineers when considering such applications. Several have already invited our Area Engineers to act as their advisers or to sit with other experts on the "prior approval panels" which they are forming.

The Board of N.I.F.E.S. has recently issued a statement, which has been circulated to all local authorities, setting out the ways in which it considers the experience of N.I.F.E.S. engineers can best be harnessed to the efforts to secure Clean Air. The statement is a measure of the Board's anxiety to be of assistance, and of its belief that the closer the collaboration all round, the quicker the progress will be. It is, of course, early days in the administration of the new Act, and undoubtedly problems will be encountered, both in administration and in engineering, before the objectives are fully realised. These may well require adjustments in the methods of collaboration between industry, local authorities and N.I.F.E.S. If so, I feel sure that they will be sympathetically examined and that my Board will make every effort to reach practical solutions. This must be so, for your objective is also ours.

Discussion

John R. Rylands (President of the Institute of Fuel), opening the discussion, said:

The two very excellent papers which have just been presented demonstrate once again that the technical knowledge for dealing with the problem of air pollution exists and that there are plenty of competent fuel technologists in possession of that knowledge. I would add the categorical statement that there was no conventional fuel which cannot be burnt smokelessly.

But despite these relatively clear and simple bases for action, the overall problem in industry, as is abundantly clear from all the papers so far read, remained tremendously complex. Technically we need not despair of eventual success, though time is needed, and patience, and in the end our achievement will be asymptotic to the ideal. Even special cases like the blue refractory example given by Mr. Jenkins can be dealt with in time. There is nothing technically impossible about subsequently burning the black smoke emitted by the intermittent kilns; it becomes an economic problem—one of cost and convenience.

But why should the blue refractory manufacturer go to the trouble and expense of installing supplementary furnaces to burn his black smoke? It would be expenditure without return, and would increase the cost of his project. Why should he handicap himself further? Has he not enough problems—what with high taxation, high wages, high material costs and all the familiar rest?

The fact is—and it is implicit in various ways in all the papers—we are faced in every direction by the need to answer the question—" Why should I? " There are many ways of starting to answer. Dr. Macfarlane has outlined the approach from the standpoint of Fuel Efficiency, and where this line can be followed the arguments may have a compelling cogency. They appeal to the pocket, not perhaps so blatantly as in former times, when an industrialist who improved his fuel efficiency was rewarded with some personal spending money. Nevertheless, there is still some financial appeal. But there are many cases where even this reduced attraction is absent, and I shall refer to these shortly.

Mr. Jenkins neatly sums up the industrial position in his Five Points. There must be a tolerant outlook all round. The industrialist is harassed in many directions, and in any event he is not the chief villain in the piece. I myself would perhaps have put his fifth and last point in stronger language, but on reflection I think that perhaps Mr. Jenkin's courteous restraint is the better way. Indeed, I would examine further some of these non-technical aspects of the larger issue. After all, we are reformers, and when we consider how we are to achieve the ends we have in view, we are very quickly confronted by the obstacles which always face the reformer.

Thus, in addition to what we may call the facts of life in this connotation, namely, the mysteries of fuels and combustion and processes, we have the eternal enigma of people. Every would-be reformer knows the three main classifications into which people naturally fall in relation to his proposed reforms. They are the Enthusiasts, the Hypocrites, and the Philistines. Each class, of course, shades into the other and indeed one man may partake at times of all three. Furthermore, each class has its graduations. The Enthusiasts ranged from the long-haired, starry-eyed apostles who dream of a perfect world in which all think alike and subscribe to the same metaphysic—to the reasonable practical people like ourselves, who steadily and calmly pursue the ideal whilst trying to be not too much of a nuisance.

The Hypocrites include on the one hand those who are vociferous in their lip-service to the cause and apathetic in their performance, and on the other, those who jump on the bandwaggon for the pleasure of the ride and the profit of the association.

The Philistines are those who just do not care, who are busy pursuing other and more profitable ends, and who salve their rudimentary social consciences with such villainous clichés as " Where there's Muck there's Brass "—inviting acceptance of the creed that the acquisition of " brass " is the dominant consideration.

Industry contains all these classes, and it would not do to suggest the proportions. But it must be evident that the techniques of persuasion, of implementation of measures, must in consequence differ widely. The exhortation which has compelling appeal for the Enthusiast may make the Philistine laugh and is merely distorted and used by the Hypocrite for his own ends.

The Enthusiast probably needs guidance and help more than anything else. Guidance is surely available in full measure, from such organizations as N.I.F.E.S. and others. Help can be given in a variety of ways, and I shall indicate one in a moment.

The Hypocrites—let us hope they are a small and diminishing number—need stimulus to make their actions suit their words. Here again, guidance—perhaps a little firm guidance, together with help—perhaps a little firm help, would seem to be the technique.

As for the Philistines, I think the sterner provisions will have on occasion to be invoked. Some powers do exist, and if they are used now and again, with patience and tolerance, the effect may be salutary. In really hard cases my own view is that the result we desire can be secured only by some form of pressure. If we have agreed that it is an anti-social act to permit the emission of black smoke into the communal air, then the penalties for persistence in such acts should be in line with those inflcted for other seriously anti-social practices. And I would not rule out the heavier penalties. Had Gilbert been alive today, he might have had a line which condemned the persistent Philistine to be kippered in his own smoke.

On the other hand, I think we must take notice of the difficulties of the industrialist who is invited to incur substantial expenditure on which the apparent return to him, as assessed by conventional arithmetic, is either nil, or is so low as to relegate the project to a low priority on his programme. I do think that genuine cases could be helped, and to this end I would urge an extension of the Government Loan Scheme to include not only, for example, chain grate stokers for Lancashire Boilers (which can usually be justified on grounds of fuel saving) but to such things, for example, as grit arrestors and dust collectors (which can very seldom be justified on such grounds). I feel that such an extension of the Scheme can be justified if only because it is the wider community that derives the main benefit, and therefore the community at large should help to ease the burden.

At present the granting of a loan requires the demonstration of a fuel saving. For fuel saving equipment this requirement should clearly be retained, but I would waive it for equipment intended primarily to reduce atmospheric pollution. In other words, I would not make a loan in this connection contingent on fuel saving. If there *is* a fuel saving, a loan can be secured now.

This is a new principle, and I commend it to the authorities. By acceptance and pursuance of it they can help towards the solution of one of our most difficult problems—that of persuading the industrialist who says "Why should I spend money without return?"

I hesitate to offer further advice to the authorities on this subject, but I myself would make the loans interest free for the first three years, and thereafter charge interest at 2 per cent. below the Bank Rate current at the period. It could perhaps be added that experience with the present Loan Scheme has shown that there are two directions in which such an extension as I have proposed could be modified. I think there could usefully be fewer forms to fill in, and a little less probing and investigating of the kind that makes the applicant feel that he is guilty unless he can prove himself innocent. I would suggest that wider discretionary powers be given to N.I.F.E.S. in this matter, and that their approval should be sufficient. For this purpose emphasis would be shifted from fuel efficiency to smokeless combustion.

Without some such aid as this, I do not see how many industries can be expected to make their full contribution to clean air. We can take for granted the enormous scope for achievement by more efficient combustion. This has been adequately covered by the papers we have heard read. The fuel economies secured in this way can be shown to justify capital expenditure, either by the industrialist himself or through a loan. But where clean air measures are *not* associated with fuel economies, and require capital expenditure, the industrialist may be in difficulties. The Act requires that he shall do something, and by and large he *will* do something. But he will often need or welcome help, and there is a logic in the community helping him in its own interest. He would still have to repay the loan, with no extra savings to assist, but the terms could be made easy for him. I commend the suggestion to the Ministry.

Finally, let me congratulate both authors again on their valuable papers, and let me assure them that, despite what I have said about the classification of humanity, I myself believe that industry in this country, on the whole, is anxious and willing to co-operate. May I add that the whole profession of Fuel Technologists are ready to guide and assist. They have many of the answers.

Alderman G. H. Goulden (Salford) said he was particularly interested in what Mr. Rylands had said of Hypocrites, Philistines and Enthusiasts. Mr. Rylands was rather concerned as to whether he should say how to put them into percentages. Alderman Goulden could tell him how they were doing it in Salford. They had been doing it for some time, and on the basis of the paper given by Mr. Jenkins.

They asked the Mayor of the City of Salford last year if he would invite all the large industries in the City to a meeting in his Parlour. Luckily his Parlour was not big enough, and more than 200 industrialists were represented at the meeting, with representatives of the nationalized Boards who dealt with fuels, himself as Chairman of the Health Committee and various members of the Council. They had then begun in the spirit of co-operation to sort out which categories the industrialists of their City came under. They told the industrialists that they believed that going to Court was not the way to put the Clean Air Act into operation. Right from the very beginning they tried to dispel the fear that the local authority was the enemy of industry, just as the local authority might sometimes state that the industrialists were the enemies of the local authority.

Alderman Goulden said he was delighted to be able to say this to the Conference. He did not know whether it was unique or the first of its kind, but they had found from that meeting quite a number of the very big industries in their City had come along to take advantage of the abilities and knowledge of their Officers and also of N.I.F.E.S. Dr. Macfarlane would know that his representative was also there. From that they had begun slowly and surely to break down this fear between the Councils and the Industrialists.

Mr. Jenkins used a phrase " local authorities must realize there may be considerable difficulties of a technical or financial nature." Of course they realized that, and they offered the facilities of the Council in tackling those questions.

In conclusion Alderman Goulden said he would like to say to those who represented industry that one of the biggest stumbling blocks in getting agreement between the local authorities and industry was not the Secretary, it was the Engineer belonging to the firm. He resented, quite rightly maybe, to some extent in some cases, the point of view that someone outside his own particular industry could advise him on what should be done.

Councillor Eric Gibbons (Brierley Hill) said that, notwithstanding the pollution caused from domestic premises, where industry existed in an area it was essential that this should be cleaned up first, as no householder could be expected to look to his domestic fire if there was an industrial chimney in the neighbourhood pouring out smoke. He reinforced the plea for loans, not only for fuel saving plant, but for grit and dust arrestors and other equipment which reduced the nuisance without saving fuel, pointing out that the industrialist received benefit when he cut down smoke on account of the fuel saving, but that this did not apply in the case of grit and dust. He further stated that in his opinion, besides the Government loan, incentive should be given to industry by permitting " Investment allowance on a wider range of Plant," i.e., payment should be allowed out of revenue and consequently receiving Tax benefits. He also stated that undue prominence should not be given to the blue brick in the ceramic industry, which was a relatively small proportion, and that care should be taken over conversions of existing furnaces from raw coal firing to one of the more expensive forms of fuel; these conversions not always being economic, due to lack of insulation, air recuperation, etc.

Sydney N. Duguid (Individual Member) said he strongly supported the views held by both speakers. He was concerned with a firm that had used the Government loan scheme to put down a new steam boiler plant and the result was a saving of 10 tons of coal a day and the elimination of all offensive smoke. He was much impressed by the businesslike way and the promptness with which all matters concerning the loan were dealt.

The training of boiler firemen and others associated with fuel-burning plant was only common sense. A stoker could make or mar the performance of almost any plant. How could the knowledge of the Chief Engineer or Charge Hand be communicated to the men on the firing floor if they did not understand what they were talking about?

A memorandum prepared by the Society on this subject would be presented for approval at the annual general meeting on the following day. He hoped it would be accepted unanimously and enthusiastically.

Alderman Mrs. A. E. Prendergast (Dagenham) said that Mr. Jenkins' paper, suggesting the need for a right approach to industry, appeared to contain an attack on public health inspectors; that surely must be based on ignorance or perhaps a rare and unfortunate isolated contact with an individual inspector; there could be no doubt, speaking generally, that the public health inspector had the right approach in dealing with industry.

The short training and certification of stokers were not sufficient substitutes for good general experience on the boiler-house floor.

In the paper the emphasis was laid on £ s. d., rather than on the health hazard of atmospheric pollution; was abatement to depend on whether or not it was a financial advantage to the industrialist?

The need for industry to dispose of its waste products was no excuse for atmospheric pollution; the cost of the removal from the premises of such wastes (if not consumed in the furnaces) could not, of course, be charged on the local rates.

H. Johnson (Esso Petroleum Co.) said that Mr. Jenkins had referred to smoke emission from ceramic kilns. It was agreed that the continuous kiln was usually blameless, but the coal-fired intermittent kiln, of the " beehive " or " bottle " type, was guilty.

However, the petroleum industry had pioneered the conversion to oil-firing of many of those kilns, and in every instance not only was smoke almost entirely eliminated, but better ware and greater kiln productivity had automatically followed.

In connection with the Clean Air Campaigns in the Midlands and North-West, his company had prepared a short film, showing various oil-fired installations. Those who had seen the film must agree that combustion was virtually smokeless. Mr. Johnson stressed that the film had been taken, in the main, from public thoroughfares, without knowledge of the personnel concerned, hence there had not been an opportunity for prior " adjustments."

E. J. Winfield (S.P.H.I., Castleford) said that as a Public Health Inspector he was appalled at some of Mr. Jenkins' utterances that afternoon. He felt that the references to Public Health Inspectors were untimely. Whilst administrative officers welcomed the views and opinions of other people, the specification for inspectors as laid down by Mr. Jenkins was unnecessary.

Public Health Inspectors as a profession had long realized the requirements of entrance to the profession and were equally alive to the technical requirements of the new Act. Public Health Inspectors had long appreciated and stressed the need for clean air but there were many people today who only recently had been converted to that viewpoint.

To any of those who felt disposed to advise Public Health Inspectors on their duties and qualities, he would refer the old English phrase of " teaching one's grandmother to suck eggs."

Mr. Winfield then made a strong plea for recognition of the Boiler Operator's Certificate as issued by the City and Guilds of London Institute. He said that the numbers taking this Certificate were increasing annually but the holding of such a Certificate did not carry any additional wage rate. He felt that industry and the trade unions should get together and incorporate the holding of the Certificate in the wage rate scheme of conditions. It would be to the benefit of both fuel economy and clean air.

Councillor C. C. Newsholme (Rotherham R.D.C.) pointed out that a certificated boiler operator could have his efforts nullified by a badly maintained plant because usually he was not the person that could do anything about faults in furnaces, flues or scale on boiler plates.

Also, in making a strong plea for a higher status for the certificated man, he wondered if it was generally known that a man holding a City and Guilds Certificate as a boiler operator was the only " City and Guilds " man *not* regarded as a craftsman.

A. Archer (C.P.H.I., Halesowen) said that the most serious gap in the local authority armoury for dealing with industrial problems was the lack of any systematic means for collecting, collating and disseminating information relating to those problems.

Each year most authorities came across problems which had almost certainly been encountered elsewhere and very likely solved or partially solved. Unfortunately, there was no ready means of finding out whether that was so. He suggested that one of the tasks of the proposed joint committees which had been referred to earlier was to collect information about problems in their areas, the steps which had been taken to deal with them, and how far those had been successful. The second stage would be to pass on that information to other authorities.

T. Steel (C.P.H.I., Crawley) referred to that part of Mr. Jenkins' paper which dealt with wood-waste incineration (reference page 37 of pre-print) and asked Dr. Macfarlane whether, in view of the obvious difficulties of obtaining smokeless combustion, he would feel confident in advising a local authority to give prior approval even for the best obtainable incinerator.

Mr. Steel also pointed out that troubles would arise from the production of waste in excess of that required for heating, leading to the tendency to " shovel it on to get rid of it." He also asked whether research in down-draught incineration had been carried out, as he had personal knowledge of a Swedish down-draught incinerator, burning cork-waste, giving very good results; and whether attempts had been made to consolidate wood-waste into briquette form to give a more easily controllable fuel.

L. A. W. Jenkins, replying to the discussion, said:

If my paper and introductory remarks stressed one angle more than any other it was to emphasize that it is essential to have tolerance and understanding between Local Authorities and industrialists if the wish and intention of the vast majority, as expressed by the Clean Air Act, is to be fulfilled.

Resistance or apathy on the one side or too inflexible an interpretation of the law on the other can well create insuperable difficulties in administering the Act, which even apart from the endless arguments that may arise out of the " escape clauses "—such as quality of coal—will provide standards which may well be impossible to define practically within narrow limits.

That a paper written without prejudice and free of duress stressing the need for co-operation could be so misunderstood by certain speakers I feel provides, in itself, the strongest argument for the plea it contained. How much more are there likely to be misunderstandings and difficulties if there should be genuine disagreement of opinion on fulfilment of the Bill.

In contrast, what a practical and stimulating idea was outlined by Alderman Goulden of Salford, and is broadly endorsed by Mr. Archer when he told the Conference that he had called together for an informal meeting, most of the prominent industrialists in his area and had discussed with them mutual problems in dealing with the Clean Air Bill.

I was most interested and not in the least bit surprised, at the very evident co-operation that this Local Authority obtained from all the industrialists. This is an enlightened approach and does stress what can be done with a common desire to solve mutual difficulties.

If this became general throughout the country, it would not only produce the right atmosphere but would have the effect particularly if suitable lecturers were present, of bringing home to industrialists the very great financial advantage to them of fuel efficiency.

There does seem to be a genuine appreciation as evidenced by most of the speakers, of the need for industry to be helped in financing measures for fuel efficiency, and this was particularly stressed where such expenditure in providing grit arrestors could not be offset by financial savings from resultant fuel economy.

It is true that the Loan Scheme does give assistance and undoubtedly its extension to cover measures specifically designed for stopping grit and dust, would be welcomed. It is to be hoped that the Authorities will take note of some of the suggestions made to this effect.

However, the Loan Scheme in itself does not remove the reluctance of the industrialist to sink capital into fuel-saving appliances when in many cases what capital he has left after taxation is required so urgently for process machinery.

Hundreds of millions of pounds, capital investment the country can ill afford, are being earmarked or spent to produce more coal, nuclear energy and to provide tankers and pipelines for oil (with all the resultant Middle East problems), a great proportion of which is required to subsidize our present waste of this country's birthright—coal.

Is it too much to hope that before it's too late a few hundred thousands of pounds in the way of tax relief, much of which will be recovered, may be granted to give the industrialist a real incentive to save. What a dynamic contribution to the Clean Air Act through greater fuel efficiency would result if all expenditure on approved fuel saving installations were to be allowed out of revenue in the year they were installed.

There did seem to be a general feeling that the encouragement by certification of Boiler House Operatives was most desirable, but I do hope that the authorities will take note of the remarks by

Councillor Newsholme that the man holding a City and Guilds Certificate as a boiler operator was the only City and Guilds man not regarded as a skilled man. Providing minimum standards are laid down for boilers over a certain size, there is no doubt today that the boiler-house operative should be regarded as a skilled man.

Finally, I would suggest that Mr. Steel's remarks are of great value. Unfortunately both by the appliance manufacturer and the industrialist, waste is too often regarded as an unavoidable evil to be disposed of as quickly as possible, and not, as it is, a valuable contribution to fuel economy.

Being for so many years a coal burning country, we have not, in the main, specialized in obtaining maximum fuel value from by-products. In other countries where, for example, wood is plentiful, plants have been designed for its efficient handling and burning to obtain the maximum calorific value. The design and efficiency of such plants is well known and it might be most desirable for our own manufacturers in this country to make equivalent plants specifically for the handling of various waste products.

I would agree with Councillor Gibbons remarks that where industry existed in an area, it is desirable that this should be cleaned up first but let this not be for the reason that industry is more easily controlled than the householder. The latter, the nationalized industries and private industry all have an equal contribution to make and this and not administrative ease or political expediency should be the aim.

To use part of Mr. Rylands' very stimulating contribution, may I suggest that the country's economy cannot afford to have the Hypocrite or Philistine when it comes to dealing with saving fuel. More than in any other field, this calls for enthusiasm on the part of everyone as in itself fuel economy can make the largest contribution to an improvement of the country's financial position.

Dr. Macfarlane, in reply, said first how glad he was to hear Alderman Goulden's account of the action taken by Salford Corporation to secure co-operation with the industrialists of that city. He felt sure that this invitation to industry to meet the Mayor and discuss the problem " in a spirit of co-operation " was by far the best means of making rapid progress towards the elimination of industrial pollution. He was grateful to the Corporation for asking N.I.F.E.S. Area Engineer to be present, and trusted that other authorities would extend similar invitations. He believed that the area engineers could be of considerable assistance.

Several speakers, including Mr. Winfield and Councillor Newsholme, had stressed the importance of the Boiler Operators' Certificate, and of according greater status to the trained man. While, personally, he agreed with them that this recognition should be put on an established basis, as was being done by the Hospital Boards, he felt it should be mentioned that the majority of industrial employers did increase the wages of their operators who obtained this qualification.

He agreed with Mr. Steel that prior approval of wood-waste incinerators raised a difficult issue. He did not think it was possible to give a general answer, since so much depended on the local circumstances, particularly on whether the material to be incinerated was reasonably homogeneous in size and whether the supply was regular.

He was grateful to Mr. Rylands, Councillor Gibbons, Mr. Johnson and others for their contributions to the discussion, but did not think the interesting points which they had made required further comment from him.

The Eighth Des Vœux Memorial Lecture.

Meteorology and Air Pollution

By

Sir Graham Sutton, C.B.E., D.Sc., F.R.S.

Director-General of the Meteorological Office

WHEN Dr. Des Vœux, whose name we honour to-day, began with others to attack the evil of atmospheric pollution, I feel sure that he must have realized that there were two great objectives in front of him. The first was to convince the inhabitants of this country that they had put up with polluted air for far too long. The second was to promote the scientific study of pollution by scientific observation, so that the remedy could be found.

The passing of the Clean Air Bill is in no small measure the result of the ceaseless activity of this Society, and I am going to assume that the first objective has now been attained. Today, no one who has given the slightest thought to the matter will deny that a dirty atmosphere is a dangerous and unnecessary evil. I shall not dwell on this aspect of your work because you would not be here if you were not convinced of this. Instead, I shall ask you to consider with me a very important part of the scientific problem, namely, the way in which smoke and gases are spread by natural means.

This, I repeat, is only one aspect of the problem of atmospheric pollution, but it is extremely important. We must accept the fact that as far as we can see into the future, we shall never entirely control the natural processes by which noxious substances emitted into the air are diffused. The real remedy, as you all know, is to stop putting such substances into the atmosphere, but since, at the present time, this is a counsel of perfection, we are justified in inquiring closely into what happens to the foreign matter when it has been introduced. This, in short, is the theme of my discourse.

All science is based on measurement, and meteorology is no exception. Much of the information available on pollution owes its origin to the pioneer work of Des Vœux and J. S. Owens on methods of measuring airborne pollution, and the regular survey of the levels of pollution in this country, organized by the Department of Scientific and Industrial Research and carried out by local authorities, is a necessary background to any scientific study of the problem. But such a survey, no matter how carefully executed, cannot supply more than broad averages, something like what the meteorologist studies as " climate," and if we want to find out precisely what is contributed by, say, a single power station, we must get down to detail. In this matter I would like to pay tribute to the pioneer work of my predecessor in the post of Director of the Meteorological Office, the late Sir Nelson Johnson. When the German Army used gas on the western front in the first world war it not only introduced a new weapon but unwittingly gave an impetus to the study of the atmosphere very near the ground—in one sense it brought about the creation of the branch of atmospheric physics known as *micrometeorology*. Much of what we now know about the spread of smoke in the lower levels of the atmosphere originated in the work of the Meteorological Department of the Chemical Warfare Experimental Station (as it was then known),* at Porton, on Salisbury Plain, from 1921 onwards. Johnson, who was the first Superintendent of the Meteorological Department, developed highly successful methods of investigating concentrations of smoke and gas downwind of sources of known strength, and thus laid the basis of the quantitative study of atmospheric diffusion. These measurements constituted for many years the only yardstick for the theoretical work, and even today, some thirty years later, I know of no data that can be said truly to surpass them. Here, if ever, is an example of the sword being beaten into the ploughshare, in that laborious and costly experiments, designed in the first instance for the purposes of war, have provided the indispensable facts for a study that cannot but promote the wellbeing of everyone.

The Lower Atmosphere

In this lecture I shall confine my attention to what is sometimes called the *biosphere*, the layer of the atmosphere in which life is most abundant. In practice this means the atmosphere within a few hundred feet of the ground. Within this layer we can ignore such complications as the effects of the rotation of the earth on the motion of the air, and we can measure any relevant properties to a high degree of accuracy by using sensitive instruments, mounted on the ground or on towers, that can be read directly. The micro-meteorologist has thus the advantage, often denied to the ordinary meteorologist, of really precise and accurate measurements, but the problems which face him are certainly not less difficult than those of the atmosphere on a larger scale. The motion of the air which we call wind is caused by pressure differences. Over flat country, such motion is mainly horizontal, but it is far from simple and it is here that the chief difficulty lies. When a gas, such as air, moves over a surface at moderate or high speed, it does not follow any fixed pattern of streamlines. Instead, the motion is highly irregular or, in technical language, *turbulent*. As human beings we feel this as a succession of gusts and lulls and rapid changes in the direction of the wind. Anyone who has looked at a field of corn in a moderate breeze must have noticed that there appear to be waves sweeping over the surface, but there is no discernible regularity in the pattern. A sensitive anemometer mounted near the surface of the earth shows that the changes in wind speed and direction are extremely irregular and of varying period, and the most sensitive electrical anemometers, used mainly for research, reveal that the changes vary from oscillations with periods of a small fraction of a second to those covering many minutes. This constitutes what we might call the " normal " state of the wind—a tumbling mass of billows of air—but there are important exceptions to this state about which I shall have much to say later.

Diffusion in the Atmosphere

It might be thought that the turbulence of the natural wind is simply a meteorological curiosity and nothing else, but this is far from true. The main effect of atmospheric turbulence is to cause large-scale mixing, and this incessant stirring up of the air near the ground has had a profound effect on the development of life on this planet. Because the wind is turbulent, seeds and pollen are scattered, water is evaporated and moved from place to place in large amounts, and cities are possible. If the atmosphere were not provided with this automatic means of mixing, man could not live in large communities; he would be poisoned by his own by-products.

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* now the Chemical Defence Experimental Establishment of the Ministry of Supply.

These facts are so striking that it is worth while pausing to examine them a little more deeply. When two gases are in contact, they mix by the process of molecular diffusion, that is, because of the incessant collisions between adjacent molecules. This is a very slow process, and if molecular diffusion alone were operative, the smoke plume from a chimney would drift for many miles as a very thin dense streak of smoke. Smoke from domestic chimneys would hang about the roof tops as an impenetrable cloud, and our streets would be almost impassable because of the exhaust fumes from cars. But nearly always, the atmosphere is turbulent and mixing is very rapid and effective. To take a concrete example, the cloud of smoke from a single source at ground level is about 40 yards wide at a distance of 100 yards downwind of the source, in a turbulent wind of about 10 m.p.h. If there were no turbulence, the cloud would be only a few inches wide at the same distance, which means that it would be exceedingly dense. This turbulence is the key to the whole problem of atmospheric diffusion, and however much we may grumble about strong, gusty winds, let us remember that it is the same gustiness that makes life tolerable, or even possible, in a densely populated community.

To study the dispersion of smoke and gases in the atmosphere thus means the detailed study of atmospheric turbulence, and this involves some of the most difficult problems in physics. Instead of molecules rushing about in a random fashion and continually changing places, we now have large lumps of air, called *eddies*, moving about in what seems to be an equally random fashion in the wind. The eddies change places, carrying with them smoke and gases, until finally what was originally a dense cloud of smoke is torn to pieces and scattered throughout a much greater volume of air. In doing so, it is greatly reduced in density or concentration and so becomes tolerable for life.

Applications of Diffusion Theory

During the last fifty years or so, the subject of turbulence has been extensively studied and a complicated but incomplete mathematical theory has been evolved. I shall not attempt to describe this theory here. It is sufficient for my present purpose to say

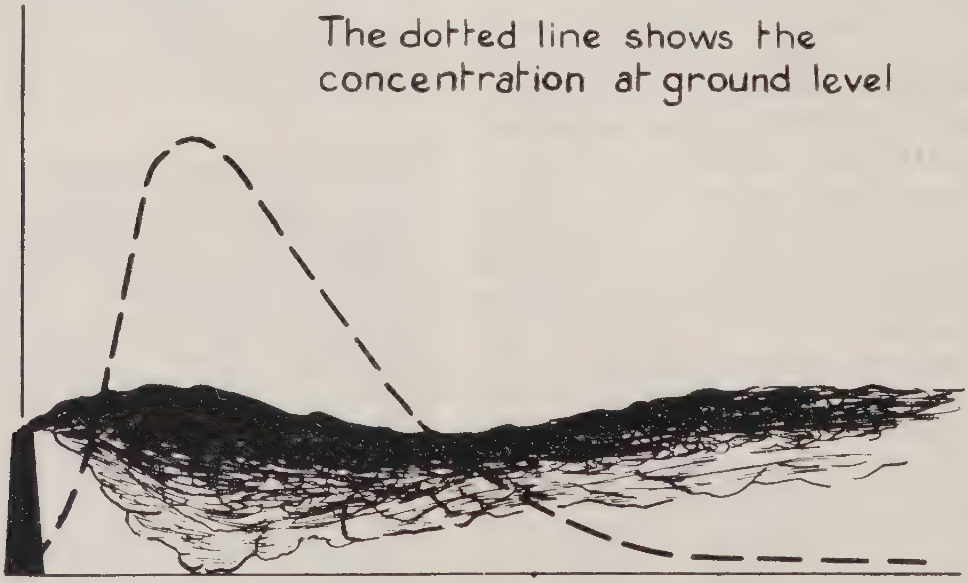

Fig. 1 Concentration from an elevated source

that we now have a basis for calculating the spread of smoke from a source near the ground, and that the accuracy of the calculations, although low by laboratory standards, is adequate for many of the problems we have in hand. Instead, I shall try to give you a picture of some of the more important results.

Consider first an industrial stack, emitting pollution as a gas or else in such finely divided particles that there is no appreciable fall-out. The mathematical theory indicates that the concentration of pollution at breathing level rises from zero at the foot of the stack to a maximum and then falls away to zero again, but rather more slowly (Fig. 1). The mathematical solution brings out one fact of major importance, that the maximum concentration varies inversely as the square of the height of the stack. That is, if the height of the stack is doubled, the maximum concentration of smoke on the ground will be one-quarter of what it was originally.

This simple result not only shows that tall stacks are very beneficial (however ugly they may be) but it also throws light on the important part played by domestic sources in creating a polluted atmosphere. If the chimney of the average house is, say, 25 feet above ground, and if we take the average height of an industrial stack to be, say, 200 feet, for equal amounts of smoke emitted the domestic chimney contributes 64 times as much as the stack to the concentration at breathing level.

This brings me to a very important point, the relative importance of industrial and domestic sources. A modern medium-size power-station, of 200 megawatts capacity, would emit about 23 tons of SO_2 per day, assuming no gas washing. A domestic fire, consuming 24 lb. of coal a day, emits about 0·6 lb. of SO_2 per day. Thus the power station emits 86,000 times as much SO_2 as the chimney, but, taking account of the height factor given above, 1 power station with stacks 200 feet high is equivalent to about 1,400 houses as regards concentration of SO_2 on the ground. If the stack height were increased to 300 feet, the height factor involved in the ground concentration would be $(300/25)^2$ or 144, and such a power-station could be regarded as equivalent to 86,000/144 or 600 houses. Thus in a town of some tens of thousands of houses, all burning coal, and supplied with electricity by one medium-size power-station, there seems little doubt that the greater part of the sulphurous smoke inhaled by those walking in the streets must come from the houses.

This point has been made very forcibly by Dr. R. S. Scorer* who has gone much further than I feel justified in doing in that he has estimated that for every ton of fuel consumed, domestic sources do £6 worth of damage and power-stations, only 8d. I doubt if these figures can be substantiated, but I think that the conclusion, that in cities domestic smoke is by far the greater source of evil, must be correct.

Inversions

The word " inversion " is now heard outside meteorological circles in connection with the smog problem. Normally, temperature decreases with height in the atmosphere up to the level of the tropopause, the base of the stratosphere, but the fall of temperature with height is by no means as regular or as invariable as, say, the fall of pressure with height. On a clear sunny day the surface of the earth is heated by the sun's rays considerably above the temperature of the overlying air. From the immediate vicinity of the ground to heights of a thousand feet or so, there is a steady fall of temperature with height, a state of affairs known to meteorologists as " lapse conditions." Because the warmer, and therefore lighter, air is below, there is a strong tendency to form upward currents in lapse conditions, and this means enhanced turbulence, and thus greater scattering

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* see, e.g. *The New Scientist*, 1, 7 (3 Jan. 1957) pp. 10-13.

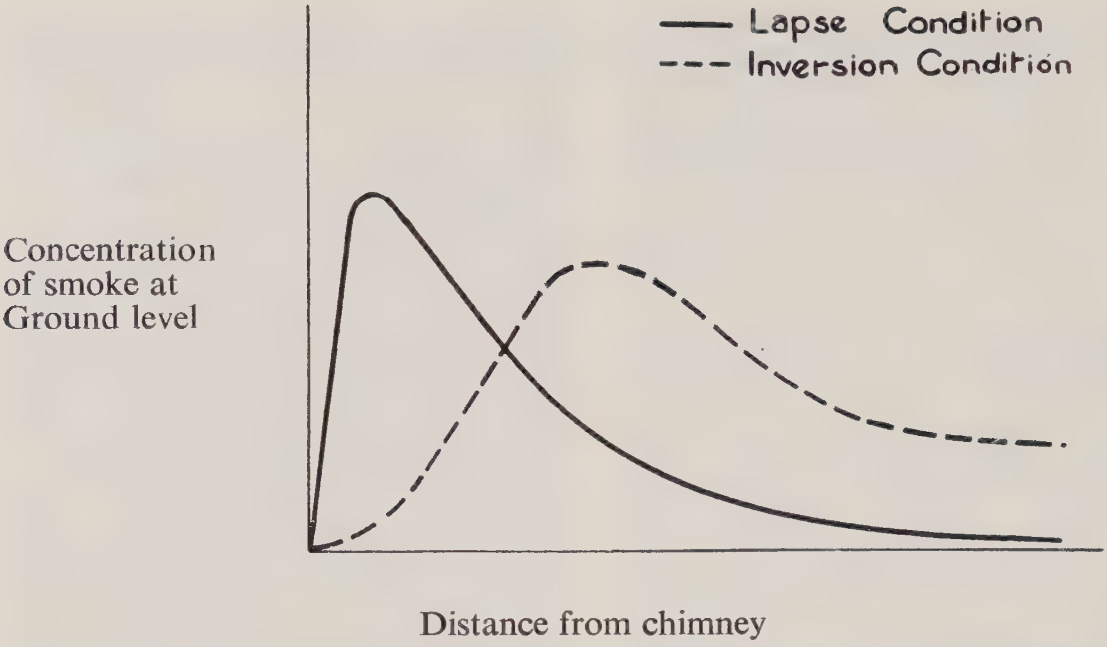

Fig. 2 Comparison of diffusion of smoke from an elevated source in Lapse and Inversion Conditions.

of pollution. Lapse conditions usually prevail from dawn to sunset, unless the sky is completely covered by a thick layer of cloud. On a clear night the reverse condition holds. From sunset onwards, the ground cools rapidly and forms a layer of cold air near the surface; temperature now increases with height, a state of affairs known as an " inversion condition." Because the colder, and therefore heavier, air is below there is no tendency to form upward currents and turbulence is suppressed.

To anyone who lives in the country, these facts are familiar, because smoke from a weed fire, which is scattered in all directions in strong sunshine, tends to drift in narrow compact plumes or sheets on a clear night. At the same time the inversion " kills the wind " and since a low wind means reduced dilution of smoke, it is evident that the presence of an inversion generally tends to have a deleterious effect on the natural ventilation of the atmosphere.

The effects of such stabilizing conditions on the theoretical distribution of smoke from an elevated source is not easily calculated, but approximate solutions have been found. Fig. 2 shows the general nature of the results. The most important feature is that in the presence of an inversion, the position of the peak concentration at the ground is displaced downwind, so that those in the immediate vicinity of the source are relieved of some of the fumes and those farther away find an increase in their pollution.

Lapse conditions are at their maximum in summer. The change from winter to summer is vividly illustrated in Fig. 3, which shows the pollution in Leicester during three winter months and also during a like period in summer.

Although the state of the atmosphere is partially responsible for the change, it is not the whole story. Domestic smoke is naturally very much less in summer than in winter, and in this example the two effects undoubtedly work together.

So far I have spoken only of surface inversions, which occur on every clear night, but smog conditions are normally caused by inversions on a much larger scale. Anticyclones are usually associated with quiet, settled weather, and in summer in the British Isles an

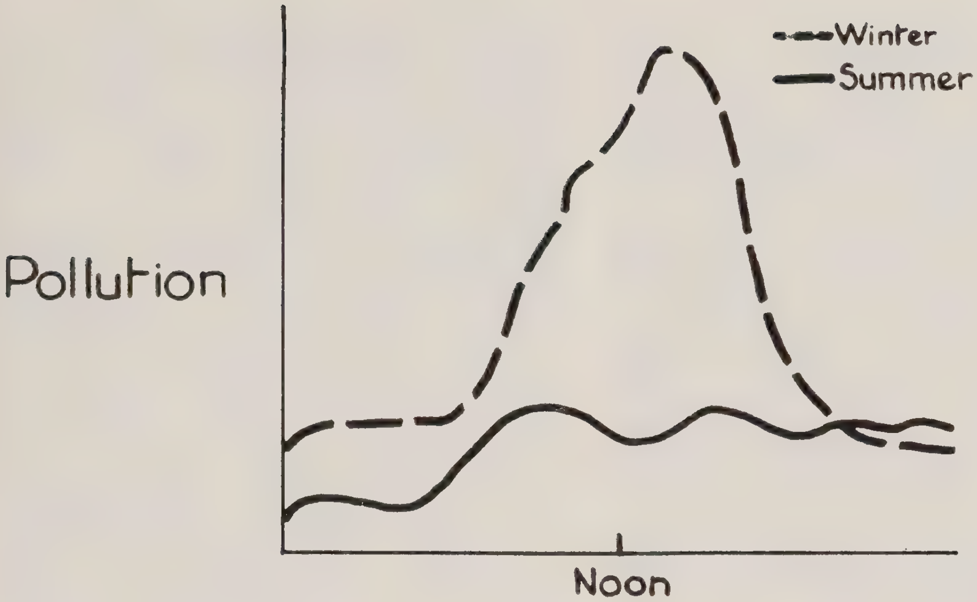

Fig. 3 Diurnal variation of pollution in winter and summer at Leicester.

anticyclone generally means, fine, warm, sunny weather, ideal for holidays. In winter, however, anticyclones may bring dense sheets of stratocumulus cloud, giving the typical winter " gloom." There is a general slow descent of air over wide areas, in the course of which the air is compressed and heated, so that a deep inversion layer is formed. This very often results in fog, and in a large city like London, the output of pollution turns it into smog.

In this large-scale type of inversion, there is an effective lid to the atmosphere at perhaps a thousand feet (or even less) above the ground. The general absence of wind and the killing of turbulence by the inversion soon make the atmosphere in a big city well nigh intolerable. In such circumstances respiratory diseases, such as bronchitis, can reach epidemic proportions, as in London in 1952.

The London smog of December 5-8, 1952, is unparalleled in the whole world as a disaster caused by pollution and it is therefore worth examining from the aspect of meteorology. The primary cause of the dense fog was the almost complete absence of wind in and around London for several days. The anticyclone which was the cause of this breakdown of the ventilation of the atmosphere reached London from the north-west in the early hours of December 5 and then became stationary. The air mass originated in the far north, and on December 6 and 7 London Airport had minimum air temperatures of 23°F. and 22°F. (9 and 10 degrees of frost) and maxima just below 32°F. Soundings of the air showed two inversions, one close to the surface and the other, caused by the descending air, higher up, but by December 7 it seems highly probable that the two inversions may have been very close together over London. The final result was that London was at the bottom of a pool of cold stagnant air, with a very effective " lid " overhead.

This pool of air contained not only vast quantities of smoke, sulphur dioxide and the by-products of the internal combustion engine, but also a great deal of water in the form of very small drops. Drops of this size can exist in the atmosphere in the liquid state at temperatures below 32°F. That is, they are *supercooled.* It is quite possible that in the 1952 smog many Londoners were breathing supercooled water drops.

One of the mysteries of the 1952 smog is why it was such an effective killer. Nearly 4,000 people died from respiratory diseases, chiefly bronchitis. Yet the measured concentrations of pollution, such as SO_2, did not surpass levels commonly regarded in industry as dangerous to health, and there are instances in the past of " London particulars " (as the famous London fogs were called) which must have been even more dirty and yet did not cause so many deaths. I have no qualifications to discuss the medical problems concerned, and I have no intention of venturing far into this extremely difficult field, but it is perhaps worth drawing attention to the fact that this smog was accompanied by temperatures below 32°F.—it was, in fact, a freezing fog made evil smelling and particularly irritating by pollution. It may well be that irritant substances, which were present in concentrations that would do little harm in warm air, became much more dangerous to those liable to bronchitic complaints, in the very cold air. Problems such as these can be solved only by statistical methods, and it is gratifying to note that there is now good collaboration between medical statisticians and climatologists in sorting out the facts.

Pollution and Fogs

We live in a country that has always been known for the severity and high frequency of its fogs, and I want now to give some consideration to the relation between pollution and fog. It is not easy to determine either the nature or extent of this relation. Meteorological statistics refer entirely to visibility and have been framed primarily to assist aviation. Thus " fog " is defined as a state of atmospheric obscurity in which visibility does not exceed 1,100 yards. Such a condition would not normally be called " foggy " by the man in the street, who would be more likely to reserve this adjective for what the meteorologist calls " dense fog," defined as a degree of obscurity in which visibility is below 220 yards. Further, no reference is made in the meteorological reports to the cause of the obscurity, which may be clean water drops, dust or smoke. Considerable care is therefore needed in interpreting meteorological visibility data in terms of atmospheric pollution.

A clean water fog and a cloud are essentially the same thing, a mass of small drops of water caused by condensation. Cloud occurs when moist air is cooled below the temperature known as the dew point, but this is only part of the story. The formation of tiny water drops from water vapour can take place only when the air contains particles called " nuclei of condensation." The exact nature and mode of action of condensation nuclei are not known, but orthodox meteorological theory suggests that most of the nuclei are specks of sea salt, with particles arising from combustion playing only a secondary role. In a maritime country such as ours there are always plenty of salt particles available, so that we may be sure that even if we could remove all pollution from our atmosphere, we should still suffer from fogs.

The problem is three-fold; how far does pollution increase the incidence, density and persistence of fogs? Let us consider first the question whether fogs are more likely to form in polluted rather than clean air. There seems to be little doubt that this is so. In the presence of an abundant supply of nuclei, condensation can take place at relative humidities as low as 80 per cent. A long series of observations made in Prague in the nineteenth and twentieth centuries show that the number of days with fog has increased with increasing pollution. My conclusion is therefore that although we cannot say that pollution is the *primary* cause of fog, there are some grounds for believing that the products of combustion act to increase the frequency of fogs by making their formation possible in lower humidities than would otherwise be the case.

The principal effects of pollution on fog seem to be in relation to obscuration and persistence, but here again it is difficult to get definite evidence, chiefly because of the unsuitable nature of the meteorological data available. Loss of visibility in a fog is primarily caused by scattering and absorption of light by the suspended water drops. Smoke appears to affect visibility in a fog chiefly by reducing the total radiation available, i.e. by cutting off sunlight, but the reduction is not great, even near the centre of a city. It is also well known to meteorologists that fog persists longer in industrial areas, so that although we can say with some confidence that smoky air makes our fogs much more of a nuisance than they need be, we are still not certain about the precise relation between pollution and fog. Fogs have always been a characteristic feature of British winters and as far as I can judge, always will be. The effect of pollution on fog is a matter for basic physical research, and I am glad to say that such research is in active progress in the Meteorological Office, especially at Kew Observatory, but as yet it is too early to quote any definite results.

The Relief of Pollution

Any discussion of the problem of fog at once raises the question of their dispersal by artificial means, and although this is hardly a matter for a conference on pollution, it is perhaps as well to state here quite categorically that fog clearance over a large area is not practicable. The amount of energy required either to create even a gentle breeze in the middle of an anticyclone, or to dry the air sufficiently to cause evaporation of the water droplets, is enormous by any standards. It is true that during the war a scheme, called FIDO, was evolved to help returning aircraft to land in foggy conditions by heating the air by petrol burners, but it must be remembered that the requirement was modest, namely, to clear for a brief period a runway 1,000 yards long and 100 yards wide, to a depth of about 100 feet. Even so, the amount of petrol consumed was very great. Dr. A. C. Best* has put the matter somewhat more vividly by asking what area of cloud, assumed 2,000 feet deep, would be evaporated if all the energy of a typical atom bomb were used for this purpose. The answer is an area about 15 miles square, that is, equivalent to a large town and its surroundings, but having cleared the air once, the process would have to be repeated as soon as fog from adjacent areas came in over the boundaries!

To return to the problem of pollution, although we cannot increase the natural ventilating power of the atmosphere to any noticeable extent, we can do something by taking advantage of the simple fact that hot air rises.

I have already explained the advantages of high chimneys. If the temperature of the gases in the chimney is kept as high as possible, the result is that the chimney height is effectively increased and ground concentrations are reduced. One of the best examples of the benefits of high stacks and high temperatures comes from America.† A large smelter at Murray, Utah, had initially a 200 foot stack. This gave high concentrations of sulphur dioxide as far away as 3 miles from the base of the stack, to the detriment of health and agriculture in the surrounding countryside. The height of the stack was therefore increased to 300 feet, which produced a noticeable decrease in the SO_2 concentrations, but later an attempt was made to improve matters still further by diluting the gases with cold air blown in by a fan at the base of the stack. The result was that the concentrations within the first half mile or so from the foot of the stack reached a level higher than those found with the 200 foot stack. The reason was not far to seek. Without the influx of cold air, the difference in temperature between the stack gases and the ambient air was 94°F. The use of the fan brought this difference down to 22°F., which meant that most of the beneficial effects of buoyancy were lost. Finally, the company increased the stack height to 455 feet and installed a coal burning heater to bring the difference in temperature between the stack gases and the surrounding air to 165°F. The result was a satisfactorily low ground concentration of SO_2. The golden rule for the designers of large industrial plants is therefore: " keep the stack orifice as high as possible and conserve all the heat you can."

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* A. C. Best, *Physics in Meteorology*, Ch. VIII. London, 1957.

† " Effectiveness of high stacks etc.' Hill, Thomas and Abersold. Industrial Hygiene Foundation.

But even this is not enough. Attention must be paid to the airflow around the orifice, to ensure that the smoke gets away cleanly. Interference with the natural airflow is very likely to happen with the high, flat roof, cliff-like structures which are so popular with architects at present. If the orifice of the main chimney of such a structure is flush, or very nearly flush, with the roof, the smoke is very likely to be swept down the lee face of the building by the " breakaway " of the air stream. In this case, the advantages of height of orifice are entirely lost, and it is important to remember that the theoretical calculations to which reference was made earlier in this paper refer, in all cases, to smoke which is carried away completely by the free wind. If there is appreciable interference by the buildings, the calculations become meaningless.

A technique has now been developed by the Aerodynamics Division of the National Physical Laboratory to give architects advice on such problems. An accurately scaled-down model of the building is placed in a large low-speed wind tunnel, and the behaviour of the smoke plume is examined by blowing finely divided paraffin oil through the orifice. The

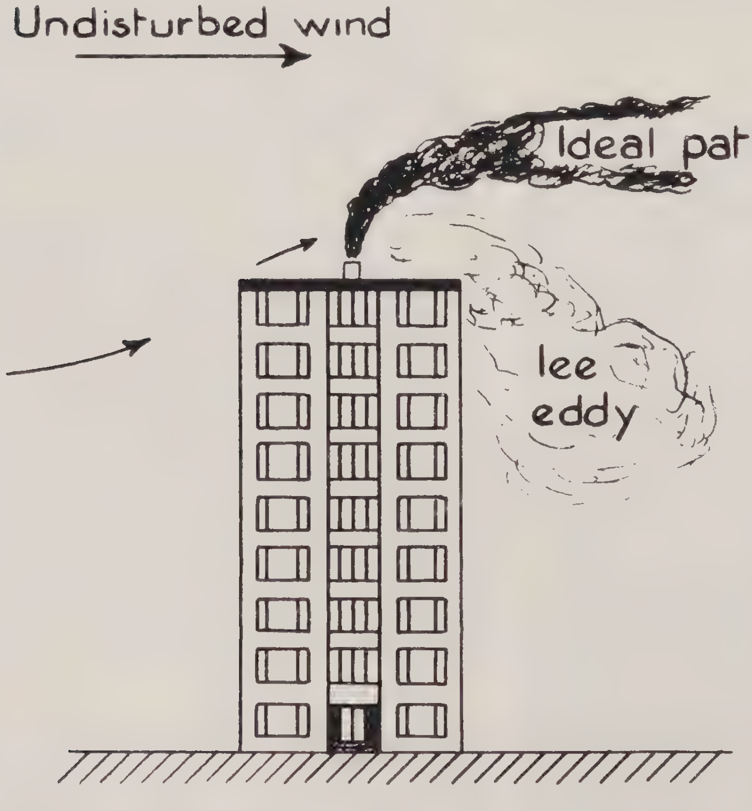

Fig. 4 The behaviour of smoke emitted from the roof of a tall building.

resulting plume is sufficiently dense to be photographed.

To take a typical example, consider a cliff-like building about 300 feet high, with a flat roof extending about 75 feet in the direction of the wind. Over the roof of such a building there would normally be a "boundary-layer" of disturbed air about 30 feet deep. Smoke trapped in this layer is almost certain to descend on the lee side of the building, and may even reach ground level near the base of the building. There are two possible ways of averting this danger. One is to erect a "chimney pot" high enough to penetrate the region of disturbed flow, but this solution does not recommend itself on aesthetic grounds. The second is to create within the chimney a forced draught so that the plume is enabled to reach the undisturbed flow by its own momentum. Naturally, conditions vary from building to building, but as a rough rule it seems that the exit speed of the chimney gases needs to be about three times that of the natural wind. For a densely built up area like Central London, this suggests that a forced draught of about 30 miles an hour at least is needed to get the smoke away from the disturbing influences of such buildings.

I have dwelt on this particular problem at some length because it illustrates the kind of technical scrutiny that I hope will become more common in the future. No one should plan a factory, a block of offices or a power station without giving most carefu consideration to the pattern of airflow. The same considerations also apply to natural topographical features. It would be of little use, for example, creating a smokeless zone if the natural course of the winds were to deflect smoke from other areas into the zone. Commonsense says that a smokeless zone, to be really effective, should be placed as far upwind (with reference to the prevailing wind) as possible, but this is a counsel of perfection that cannot always be followed. What is necessary is that those responsible for planning should realize that today technical advice is available which could enable them to mitigate many of the evils of pollution. It is regrettable that such advice is not sought as frequently as it might be.

Conclusions

The picture I have tried to put before you in this necessarily brief sketch is that of meteorology as a science which is useful in ways other than that of forecasting weather, and in particular for giving help in problems of pollution. The micro-meteorologist has a great deal to give the community, and it is my hope that his services will be in demand more than ever in the future. As the Head of the national meteorological service I can give a very whole hearted assurance that we shall do everything in our power to help the Society in its most praiseworthy crusade for a clean atmosphere.

CONFERENCE RESOLUTION

STATEMENT ON THE TRAINING AND QUALIFICATION OF BOILER OPERATORS

The following resolution was proposed on behalf of the Executive Council during the final session of the Conference, which was carried with two dissentients:

"THAT this Conference of the National Smoke Abatement Society endorses the Society's Statement on the Training and Qualification of Boiler Operators, and urges Local Authorities, Industry and the Trade Unions concerned to give it their close and active attention.

"The Conference further urges

Local Authorities themselves to act with respect to boiler operators in their own employment by providing incentives to encourage training and qualification."

The Statement

The Statement referred to in the resolution, with an explanatory footnote added, is as follows:

1. Much of the success of the new Clean Air Act in preventing industrial smoke will depend on the skill and knowledge of the boiler or furnace operator. It will either be very difficult or impossible for an untrained man to comply with the Act and avoid the emission of dark smoke even from good plant. Also, as has been said before, a careless or unqualified operator may waste in a day as much coal as a miner can produce in a day.

2. The training of stokers and holding of local qualifying examinations was pioneered by the forerunners of the National Smoke Abatement Society nearly 50 years ago, but apart from a very few centres progress in expanding this work has been slow and a great deal remains to be done. Now, however, examinations have been put on a national basis through the introduction of the Boiler Operator's Certificate of the City and Guilds of London Institute. The difficulties associated with the setting up of classes at technical schools and colleges in some areas have been overcome by the development of Home Study courses with one-day monthly group meetings. This latter method has been used with success by the National Coal Board, the Central Electricity Authority and the National Industrial Fuel Efficiency Service.

3. It is considered that the final objective should be that *all* boiler operators (and particularly all those on hand-fired plant) should be qualified by examination. The earning of such a qualification, as in any other case, should carry with it a higher status and rate of pay, or be recognized by the addition of a bonus to the standard rate. It is useless—and clearly unfair—to encourage men to take the courses and examinations without such incentive and recognition. There are a number of instances where such recognition is already being given with success.

4. Employers should encourage operators to take the courses by facilitating attendance either at local classes or at the monthly group meeting held in conjunction with home study courses. It is also urged that they should assist, in appropriate circumstances, with fees and travelling expenses.

5. The Society therefore urges, as a first step, that local authorities, industry, the trade unions and technical schools or colleges should confer together for the purposes of organizing and then publicizing, local arrangements through which all boilermen will be able to take courses and examinations. A small representative committee in each area might be set up to maintain the initial impetus.*

6. In conclusion, we reiterate the importance of the proposals made in this Note on the grounds of their value to:

(1) *The Community* by the reduction of smoke that can be achieved by the employment of trained operatives.

(2) *Industry* by the saving of fuel that a trained operator can help to achieve.

(3) *The Operator* by giving him a better status and remuneration.

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* In some areas existing fuel efficiency, further education or similar committees may be working on these lines or may be prepared to do so. The purpose of the committees suggested above is to stimulate local interest and recruitment rather than to organize courses, which can usually be done through existing channels.

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NATIONAL SMOKE ABATEMENT SOCIETY
Palace Chambers, Bridge Street, London, S.W.1

HASTINGS CONFERENCE

2nd-4th October, 1957

Members and Delegates Attending and Authorities, &c., Represented

Page

Alphabetical List of Members and Delegates **2**

List of Local Authorities Represented and Delegates Appointed **10**

List of Associations, &c., Represented and Delegates Appointed **18**

List corrected to 25th September; for additions and alterations inquire at the Conference Bookstall

National Smoke Abatement Society

Hastings Conference, 1957

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Taylor, M. Lindsay (see Programme)
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Thomas, Cllr. T. L., *Neath R.D.C.*
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Wallwork, T., *East Midlands Division, National Coal Board*
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Walvisch, Cllr. H., *Stepney*
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Ward, G. A. (SPHI), *Hartlepool*
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Watts, Cllr. Miss N. K., *Merton & Morden*
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Webster, W. (CSI), *Clydebank*
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NATIONAL
SOCIETY FOR CLEAN AIR

(Formerly National Smoke Abatement Society)

Proceedings of the Llandudno Conference 1958

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CONTENTS

Index to Contributors 4

Summary of Events 5

Address by the Rt. Hon. Henry Brooke, M.P., Minister of Housing and Local Government 7

Presidential Address, by Dr. R. Lessing 12

Session 1—Industrial Aspects of the Clean Air Act

(1) The Control of Black Smoke Emission, by G. W. Farquharson .. 20

(2) Grit and Dust Emission, by Thomas M. Ashford 25

(3) Height of Chimneys, by Norman Bastable 34

Discussion 42

Session 2—Forum on Smoke Control Areas

Reports from the Society's Divisions:

Scotland, by John Innes 52

North East, by Geo. W. Tate 52

North-West, by A. E. Snodgrass 54

Yorkshire, by James Goodfellow 57

West Midlands, by George W. Farquharson 59

East Midlands, by Alfred Wade 61

South-East, by J. J. Matthews 62

South-West (Bristol and West Clean Air Committee), by F. J. Redstone 65

Review of the Reports, by Dr. Llewelyn Roberts 66

Discussion 67

Session 3—Scientific and Technical

Air Pollution in London and its Smokeless Zones, by T. S. Pindard and Dr. E. T. Wilkins 72

Air Pollution and Respiratory Disease, by Dr. D. D. Reid 79

Hazards from Air-Borne Radioactive Matter, by G. B. Courtier 85

An Automatic Smokeless Stoker for Central Heating, by D. V. Brook and Dr. S. W. Burke 92

Discussion 96

The Des Voeux Memorial Lecture

Clean Air, Urban Amenity and the Growth of Towns, by Sir William Holford 101

INDEX

To Authors and Participants in Discussion

Page
Ashford, Thomas M. 25
Ashworth, Cllr. Dr. H. K. .. 67

Barker, Ald. Mrs. A. L. .. 70
Bastable, N. 34, 51
Beardsley, Cllr. W. A. 44
Boyd, Miss Dorothy 68
Brimelow, Cllr. C. L. 68
Brook, D. V. 92
Brooke, Henry, the Rt. Hon. .. 7
Burke, Dr. S. A. .. 92, 100

Coe, Arthur 44
Cook, Cllr. E. W. 67
Cooper, Dr. W. J. D. 98
Courtier, G. B. 85, 99
Crawford, C. H. 49
Craxford, Dr. S. R. 97

Dhenin, G. W. 97
Dilworth, Cllr. John xx
Draper, P. 44

Farquharson, G. W. 20, 59

Goodfellow, J. 43, 57, 96

Hayward, C. H. G. 96
Holford, Sir William 101
Houlbrooke, A. 97

Innes, J. 52, 70

Page
Jackson, Dr. R. 47
Jones, Cllr. W. A. Norman .. 43

Lessing, Dr. R. 12
Lowbridge, H. E. T. 49

Mair, L. 70
Matthews, J. J. 62

Nonhebel, G. 42

Parker, Dr. Albert 50
Pindard, T. S. 72

Rainger, Cllr. H. 69
Redstone, F. J. 65
Reid, Dr. D. D. 79, 99
Riley, J. S., Jnr. 69
Roberts, Dr. Llywelyn 66
Robertson, Dr. J. S. 69
Robinson, Ald. Dr. J. 68

Scott, M. F. 71
Smith, Cllr. William 69
Snodgrass, A. E. 54, 65
Spence, K. L. 98

Tate, Geo. W. 52, 70
Thomas, E. G. 68
Tonkin, D. G. 48

Wade, Alfred 61, 70
Watson, Cllr. C. A. 46
Wattleworth, W. H. 47
Wilkins, Dr. E. T. 72, 99

SUMMARY OF EVENTS

THE Conference was held in the Pier Pavilion, Llandudno, and for the first time at the Society's conferences a Clean Air Exhibition was held in conjunction with it. The attendance was again a record, with 778 members and delegates.

The proceedings opened on the morning of Wednesday, 1st October, with the President, Dr. R. Lessing, in the Chair. The Chairman of the Llandudno Urban District Council, Councillor Harold Neville, J.P., was the first speaker, conveying a welcome to the town to the Conference and wishing it success. He was followed by the Minister for Housing and Local Government and Minister for Welsh Affairs, the Rt. Hon. Henry Brooke, M.P., whose address is contained in this volume. Then followed Dr. Lessing's second Presidential Address.

On the Wednesday afternoon, with Mr. John Innes, Deputy Chairman of the Executive Council, in the Chair, the Conference discussed the industrial aspects of the Clean Air Act and the papers presented by Messrs. G. W. Farquharson, Thomas Ashford and Norman Bastable.

On the Thursday morning the Conference took the form of a Forum on Smoke Control Areas, with a platform consisting of the authors of the reports presented on behalf of the Society's Divisions, and a " panel " of experts. The reports were reviewed, before the general discussion, by Dr. Llywelyn Roberts.

The Chairman for this session was Dr. J. L. Burn, a Deputy Chairman of the Council.

Technical and scientific papers were presented at the Thursday afternoon session, with Dr. T. P. Colclough, Chairman of the Society's Technical Committee, presiding. The authors were Mr. Pindard and Dr. Wilkins of the Fuel Research Station, Dr. Reid of the London School of Hygiene and Tropical Medicine, Mr. Courtier of the London County Council, and Mr. Brook and Dr. Burke of the British Coal Utilization Research Association.

The Chairman of the Executive Council, Dr. J. S. Burnett, presided at the Des Voeux Memorial Lecture on the Friday morning and during the Annual General Meeting which followed. The Lecture, by Sir William Holford, was received with keen interest and appreciation.

At the Annual General Meeting the election was announced of Sir Hugh Beaver, in succession to Dr. Lessing. Sir Hugh was unfortunately unable to be present, but the following message received from him was read by Dr. Lessing:

> " I am very sorry that longstanding previous commitments make it impossible for me to be with you at Llandudno at the beginning of October. I have indeed to lead a deputation of British industrialists to discussions in Rome with similar representatives of Italian industry. You will appreciate it is impossible for me to default. I should be grateful if you would convey to the Annual General Meeting my apologies for my absence; and convey my deep appreciation of the honour that they do me in inviting me to follow such a distinguished line of Presidents of the Society ending with yourself.
>
> " Members of the old National Smoke Abatement Society and even earlier of the Coal Smoke Abatement Society may properly feel satisfied with the results that have been achieved. But the greatest achievement is the recognition of the fact that what we are entitled to is Clean Air. The Society under its new name therefore steps forward in pursuit of a new goal and a new objective. I shall do anything that I can to assist in this campaign which is bound to be a long one."

Nominations for the new office of Senior Vice-President are made by the Executive Council, and it was announced that an invitation to this office had been made to and accepted by Sir Graham Sutton, F.R.S. The election of

Mr. S. E. Cohen as Hon. Treasurer and of the Divisional Representatives to the Executive Council were reported. The Audited Financial Statement for the year ended 30th June, 1958, was presented and approved, and an oral interim report on the Society's activities was given by the Chairman. A resolution to amend the Society's Bye-laws in respect of the rates of subscription for local authority and corporate members was moved and agreed to without dissent.

Following the Annual General Meeting two conference resolutions were moved and after discussion were carried by a majority of those present and voting.

The first, on behalf of the Chesterfield R.D.C., was spoken to and moved by Mr. James Law, and read as follows:

> That this Conference of the National Society for Clean Air is of the opinion that the concentrations of acid gases permitted by Sections 6 and 7 of the Alkali, etc. Works Regulations Act 1906, in the manufacture of sulphuric acid and the concentration or distillation of sulphuric acid are greatly in excess of what ought to be permitted in the present drive for cleaner air, that the discharge of acid gases within these tolerances can and does cause great discomfort and distress to persons within the area of discharge and requests the Executive Council, through the Technical Committee, to investigate the question with a view to making representations to H.M. Government.

The second, moved by Councillor Jennings for the Bolsover U.D.C., was as follows:

> That this Conference considers that as a means of giving practical encouragement to the occupiers of private dwellings to install smokeless appliances in their premises, the Minister of Housing and Local Government be requested to secure the amendment of Section 12 of the Clean Air Act, 1956, so that the grant of appropriate financial assistance is available in respect of any private dwelling irrespective of whether the premises come within a smoke control area or not, subject to the condition that where a grant is made, only those fuels authorized for use in a smoke control area shall be used for such appliances.
>
> This Conference is of the opinion that the payment of such a grant in advance of formal action would produce immediate benefits by reducing atmospheric pollution, and would also ease the financial burden on Local Authorities when formal steps are taken to declare smoke control areas.

On the Wednesday evening the Conference enjoyed the hospitality of the Chairman and members of the Llandudno U.D.C. at a Reception. On the Thursday evening a film show was arranged in one of the town cinemas, where films of clean air and general interest were shown by courtesy of the Electrical Development Association, the Gas Council and Shell Mex and B.P. Ltd.

A general vote of thanks was moved, at the close of the Conference, by Dame Vera Laughton Mathews, Past-President. Amid applause she expressed thanks and appreciation to all who had made the Conference and Exhibition so successful, including the Chairman and Officers of the Llandudno U.D.C., Mr. E. Victor Williams, Publicity Manager, and the staff of the Llandudno Publicity Association, the Management and staff of the Pier Pavilion, the Exhibitors and their staffs, the Authors of papers, sessional Chairmen, and those who participated in the discussions, the Chairman, Mr. J. J. Matthews and members of the Conference Committee, and the members of the Society's staff.

Address

By the Rt. Hon. Henry Brooke, M.P.,

Minister of Housing and Local Government

I AM determined to make the Government's Clean Air policy a success, and I welcome this opportunity to address the Conference of the National Society for Clean Air.

I congratulate the Society on its new title. Your title recognizes that the purpose now is not only smoke abatement, but the suppression of air pollution in all its forms.

As Minister for Welsh Affairs, too, I welcome the fact that we have all come together here in Wales. The splendid air of Llandudno is free from man-made pollution, or almost so. No one can truly say that of all parts of Wales—yet.

Your President, Dr. Lessing, this year completes half a century's association with the Society and its predecessor. His untiring work in the struggle against air pollution on behalf of the Society and in his personal capacity is legendary. We are all of us delighted that this year Her Majesty should have been pleased to appoint him a Commander of the Order of the British Empire.

The Society, of course, is drawing near its Diamond Jubilee. In 1959 it will be sixty years since the establishment of the Coal Smoke Abatement Society in London. Events in the Society's history seem to have a habit of falling in the ninth year of each decade. The Smoke Abatement League of Great Britain, concerned mainly with the provinces, was set up in 1909. The National Smoke Abatement Society was formed by the amalgamation of the two parent organizations in 1929.

I hear that the Society proposes to mark the Diamond Jubilee by holding an International Conference and Exhibition in London during October next year. It is worthy of the tradition of the old National Smoke Abatement Society that, in celebrating its Jubilee, the Society should be looking not inwards but outwards, and be concerned to share its knowledge and experience with representatives from overseas. I know there is a growing recognition of the menace of air pollution not only in the United States but in many countries within and without the Commonwealth.

As we are now the country with the most advanced system of legislative control over air pollution, our experience may be of value to others. But we have also much to learn, and we need not be ashamed of saying so. International co-operation is highly desirable in assessing the problem of air pollution and in devising remedies. Both O.E.E.C. and the World Health Organization have initiated joint studies and conferences on clean air problems. By pooling the varied experience of different countries and by sharing the techniques for mitigating smoke and fumes and dust from industrial processes which present special technical difficulties, the time taken in mastering these problems in each individual country can be greatly reduced.

The other major event of 1958, challenging in importance the Society's change of name, took place on June 1st—the " Second Appointed Day "—the day on which the Clean Air Act came fully into force. The introduction on that day of the industrial parts of the Act was accompanied by my issuing three sets of regulations.

The Dark Smoke Regulations

First, there are the dark smoke

The Minister and Platform at Llandudno

regulations. They prescribe the maximum limits for emissions of dark smoke from buildings. They set the standard of smoke emission from industrial furnaces. The time limits—basically ten minutes in eight hours—are exacting without being unduly onerous. They will be observed only where furnaces are fired efficiently, and are properly maintained and operated. The limits are related to a period of eight hours in order to correspond with normal shift working. From the point of view of local authorities who have to administer the Act, a shorter period permitting continuous observation would have been easier to enforce; but one has to take account of the normal cycle of operations in the boiler-house.

There are other important limitations in the regulations which will of course assist local authorities in enforcement—the limit of four minutes for continuous dark smoke, and the prohibition of more than two minutes black smoke in thirty minutes.

Secondly there are new regulations dealing with dark smoke from ships. They allow, for the time being, rather longer limits than those applying on land. Often the difficulties in the way of adapting ship's boilers to comply with the Act are formidable, and further work is needed to improve the smoke eliminating devices for marine boilers. This is being undertaken by the Fuel Research Station of D.S.I.R. in conjunction with the shipping industry. When it is completed and the new devices can be manufactured, we shall see whether some tightening of the regulations is practicable. But the problem of controlling smoke from ships will always be more difficult than with installations ashore, because of the varying and often exacting conditions on the water.

Scheduled Processes

The third part of the preparations for June 1st was the Order extending the Alkali Act to additional industrial processes which give rise to technical questions of difficulty and complexity in the prevention of smoke, dust and grit.

In listing the processes to be brought under the Alkali Act, we took great care to schedule only those which do present difficult or intractable problems. We were concerned not to cast the net too widely, or to deprive local authorities of control over works where they were quite competent to exercise it. The balance is probably about right, bearing in mind that the Order is of general application—it applies to all local authorities, small or large—and there is a procedure in subsection 2 of section 17 of the Clean Air Act which enables control to be transferred from my Department to individual authorities in suitable cases.

Applications for this will be considered on their merits, taking into account the experience and capacity of the local authority and the nature and problems presented by the processes over which they are seeking control. Two authorities, Sheffield and West Bromwich, have so far submitted applications; consultation is about to take place with the industrial firms who might be affected by an Order based on their proposals.

There seems to me occasionally to be some misunderstanding of the working of the Alkali Act and the effect of the new Alkali Order. Anyone familiar with the Alkali Act of 1906 will remember that it talks about a " work," such as a sulphuric acid " work." Nowadays we should probably refer to a " process," or perhaps to the plant in which the particular process is operated.

It is sometimes assumed that if certain processes have been registered under the Alkali Act, then the whole of the premises or " works " comes under the Alkali Inspector. That is not so. The Alkali Inspector deals only with the plant concerned with scheduled processes. Anything else which is not part of the scheduled process comes under the local authority and the Clean Air Act.

It is important that the processes which come under the Alkali Act and under the Clean Air Act should each be clearly known. We are proposing to inform local authorities of all the registered processes in their districts, as soon as the registration of all the works now coming under the Alkali Act is completed.

Before the 1958 Order there were some 830 premises conducting about 1,600 registered processes under that Act. Registration is not quite complete, but the latest figures available indicate that about 2,100 premises with some 3,400 processes or installations now are under the Alkali Act. This may sound a lot, but the numbers are of course quite small compared with the enormously greater number of boiler and furnace plants of all kinds which local authorities are responsible for watching under the Clean Air Act.

To deal with this increase in the work of my Alkali Inspectorate the number of Inspectors actually on the job has been increased from 10 to 20, and we are aiming ultimately at 28. With this team of men, all of them chemical technologists qualified not only academically but by their practical experience in industry, we should be well placed to attack the more intractable kinds of industrial pollution by smoke, grit and dust. We see this as a joint operation, calling for a united effort: certainly not as a battle between the Alkali Inspectors and industry, certainly not as a tug-of-war between the Inspectors and local authorities. The enemy is not one another. The enemy is air pollution. It is the common foe of us all, and we all are allies in making relentless war on it.

So you can be sure that on the industrial side we now have legislation which should prove effective in dealing with a broad range of air pollution problems. Of course we have not reached perfection. Of course we must not expect to achieve 100 per cent. clean air forthwith. Of course there are all sorts of practical difficulties ahead. But we are the first country in the world to introduce a complete system of legislation for dealing with the problem on a national basis.

If we can attain sensible and forceful and consistent administration by local and central government, and if we can get the co-operation of the man in the street and the man in the boiler-house and the woman in the home, the Act can achieve the Government's purpose and yours: and that is to reduce smoke, grit and dust in our towns and cities to a level unknown for a hundred years or more. This is my determined intent.

On the industrial side we ought to see a substantial improvement within the next five years or so. The period allowed by the Act for alterations to plant expires in the middle of 1963. During this time all the necessary improvements to furnaces and boilers will have to be carried out—the fitting of mechanical stokers, and the provision of instruments for observing and checking smoke. There ought also to be a steady growth in the fitting of dust and grit arrestors to furnaces.

In the processes which come under the Alkali Act there should also be improvements coming along by then. For instance, in the gas and electricity and pottery industries the process of shutting down older works and installations will have gone yet a stage further; and it is the older plant which so often is responsible for the most smoke.

Smoke Control Areas

Now about pollution from house chimneys. Nearly 500 local authorities have adopted the Model Byelaw requiring the installation in new buildings of domestic appliances which are capable of using smokeless fuels. Most of the authorities in the black areas have done so. This means that over a wide part of the country new houses will be equipped with the right appliances from the start, and there will be no need to spend money on converting fireplaces to burn smokeless fuels.

The development of smoke control areas is speeding up. My department has been notified of proposals for 182 smoke control areas from 108 local authorities. They relate to nearly 200,000 premises and about 33,000 acres of land. This is not bad going considering that the Clean Air Act has been in force only some twenty months. But of course it is but a start when measured by the task that lies ahead.

There are seven million houses in the " black areas," as well as hundreds of thousands of shops, offices and similar buildings. The black areas extend over 3 million acres. We have a long way to go.

The time is coming when we may need to look systematically at what local authorities propose to do in future years. But we have made a useful start; and the first Smoke Control Orders under the Act have been coming into force this year. There will be twenty-eight of these Orders in operation by Christmas.

When my colleague Lord Mills spoke to the Society at your conference in Hastings last year he stressed the importance of educating people about the evils of air pollution: informing them rather than exhorting them: presenting facts that will combat prejudice and ignorance.

Publicity

People are becoming more aware that smoke and dust and grime are a menace to health and happiness: but not everybody has yet realized that it is usually possible and quite often easy to do something about it.

This year there has been more helpful publicity in the Press on the subject of clean air than ever before—particularly at the time of the Second Appointed Day. Many good leaflets and booklets have been published about the Act and about means of complying with it. My Department has produced memoranda for local authorities, and we shall shortly be publishing a short explanatory leaflet about smoke control areas which local authorities can give to householders in those areas.

We have also produced a short television film for showing when fog warnings are broadcast. That will be available this winter if fogs threaten.

Of course your Society has long been active in clean air publicity. It is skilful and experienced in presenting the facts. I am glad that the splendid work of education carried on in the regional clean air campaigns is to continue in the West Riding. The prominent part which the Society plays in these campaigns is, in my view, of the utmost value.

The benefits to health, the avoidance of fuel wastage and economic loss, the prevention of damage to buildings and materials, the greater cleanliness and the less drudgery—these may be familiar texts, but they cannot be too often repeated.

I believe the Clean Air movement can make a still wider appeal. The clean air campaign is a movement to stir the senses, a movement which can contribute to the bettering of the very essence of town life in this land of ours.

One evil effect of the film of impurities which hangs over towns is that it reduces the light of the sky and makes the whole scene dimmer, less cheerful, less colourful. Pure air has an extra value because it sharpens outlines and intensifies colours. One gets an impression of a greater keenness of the senses when the atmosphere has been washed by rain. Our ultimate aim must be to make towns and industrial districts not only cleaner and more presentable, but more exhilarating places to be in.

I am the Minister charged with responsibility for town and country planning as well as with what are called the environmental health services—housing, water supply, sewerage, refuse disposal, clean air, and so on—and I can see, better than most, perhaps, the kinship these have with one another.

As towns become cleaner and healthier, we can think again about making them beautiful. Trees will grow more vigorously, particularly the many kinds which hate a smoky atmosphere—you will see that point made in my Ministry's little book on *Trees in Town and City* that is now being published.

Perhaps we shall need a campaign to get houses painted brightly and buildings cleaned—to give the towns a new look as the tide of smoke is driven back. Certainly architects will have to think harder about colour. As the purity of the light in the centre of big towns improves, the colour of paint will not only remain bright longer, but will appear more intense. Discriminating use of colours in brickwork, roofs and facing materials generally, as well as in paint, will become more rewarding than for years.

We shall have to study more intensively colour qualities of different local stones and other building materials, and the harmonies which can be achieved by picking out the surroundings of doors and windows in colour. One can see that growing nowadays in the mining valleys of South Wales.

You have done well to get Sir William Holford to give the Des Voeux Lecture this year. His theme—" Clean Air, Urban Amenity and the Growth of Towns "—is a reminder that the aims of the clean air campaign are not merely to remedy the blight of air pollution.

The tendency for towns to grow outward into the country, and for people to live away from the towns in which they work, is not simply due to the pressure of population or the need for more house space. I am sure it reflects a desire to escape from drabness and dimness. Let us see if the campaign for clean air can be linked with a campaign to make towns beautiful, and life the sweeter for it all.

The Presidential Address

Clean Air on the Way

by

R. Lessing

C.B.E., Ph.D., F.R.I.C., F.Inst.F., F.Inst.Pet., M.I.Chem.E., Hon.M.Inst.Gas.E.

IN my Address to last year's Annual Conference I referred to the painfully slow progress of the smoke abatement movement during the first half of this century, which might have been still less effective or never been initiated, had it not been for the efforts of this Society and its predecessors. But these activities were by no means unavailing. They resulted in creating an attitude of mind which only required the trigger action of the unprecedented severity of the London smog of December, 1952, to release a pent-up feeling, nation-wide, that drastic steps for the abolition or abatement of air pollution must be taken.

In very few years the situation has undergone a remarkable change. The Beaver Committee was set up and its findings and recommendations met with universal approval by press and public. The Clean Air Bill, largely based on the Committee's Report, passed through both Houses of Parliament with unusual celerity due, no doubt, to its being lifted—contrary to previous smoke legislation—out of the political arena and being welcomed and supported by all parties.

The final order prescribed by the Act came into force on 1st June, 1958 and its full implementation is now well under way, except in Scotland.

A corresponding, not inconsiderable change has taken place in our Society within the two short years during which I have had the honour of occupying the Presidential Chair. It has adopted a new title and one which signifies more than a mere change of name, for it registers a logical development. The parent Society was appropriately called The Coal Smoke Abatement Society because coal was the type of fuel then mainly concerned. When, in 1929, the three organizations operating in London, the Provinces and Scotland joined forces to form The National Smoke Abatement Society, the use of oil fuel had progressed and the restriction to coal smoke was no longer justified. The recognition that smoke is not the only objectionable pollutant but that gaseous and especially acid impurities are probably of even more damaging character, has steadily been gaining ground. Also, as a result of the Clean Air Act, it is to be expected that in the foreseeable future the emission of domestic smoke will diminish at the rate at which control areas are established, while dark industrial smoke will be reduced to a minimum. For these reasons and on the psychological ground that " Abatement " indicated a certain diffidence of purpose, the title " National Society for Clean Air " was adopted as implying conviction of positive achievement.

To give effect to this conviction the Society must not allow itself to rest on its laurels, but must redouble its efforts in a wider and more comprehensive field.

The part played by the Society in preparing the ground for workable legislation is acknowledged on all sides. It has sown the seed but must not regard the passing of the Clean Air Bill as the fruit grown from it, but rather as a delicate plant which needs assiduous tending and fertilizing to bring it to final fruition.

MAKING THE ACT SUCCEED

It will be useful to examine the steps to be taken to attain the best results from the working of the Act and to envisage objectives that are beyond its scope. This may be done under the two main headings of administrative and technical measures.

Administrative Action

Until fuel users and others of their own accord, regard the avoidable discharge of impurities into the air as unthinkable, just as they have for a long time regarded the disposal of sewage into open street gutters, the creation of smoke control areas offers an effective means of preventing or diminishing pollution. It is obvious that the work and expense involved in making the necessary surveys, installing, adapting or replacing appliances, ensuring the supply of suitable fuels and eventually supervising the control, will cause Local Authorities to proceed cautiously in selecting and establishing smoke control areas. But whilst their powers under the Clean Air Act are permissive they should exercise their discretion generously and without undue delay if the intention of the legislators to abolish air pollution is to be met within a reasonable period of time, more especially in the densely populated and highly industrialized "black" districts.

As was to be expected, Councils had to get used to the idea of exercising their new powers and to familiarizing themselves with the procedure to be followed. This meant a slow start, as is shown by the figures in Table 1, giving the position at the end of July. 1958.

TABLE 1

Progress of Smoke Control Areas in England during Period ended 31st July, 1958

	Areas	*Acreage*	*Premises*
Smoke Control Orders confirmed	34	3,753	24,037
Submitted for confirmation but not confirmed ..	22	4,265	25,101
Proposals notified to the Minister	109	20,828	125,131
Local Authorities told to proceed to detailed survey	2	590	2,360
Smokeless Zones and Smokeless Areas under Local Acts	21	3,274	39,876
Local Authority Housing Estates made or to be made smokeless by tenancy conditions.. ..	13	1,542	14,342
	201	34,252	230,847

In Scotland, one order comprising 139 acres and 1,007 premises has been confirmed by the Secretary of State. Five proposals relating to 1,959 acres and 9,544 premises have been made but not yet confirmed.

Whilst the results show a small beginning, the example set by the Authorities concerned is likely to have a snow-balling effect of a progressively faster rate of Orders made and confirmed.

The " repeat orders " for additional areas by some Councils are of particular significance.

Co-ordinating Smoke Control

The gradual extension of smoke control under the jurisdiction of individual local Councils must be welcomed, but it really does not go far enough. The slogan " Air Pollution has no boundaries " has become somewhat hackneyed, but it remains valid all the same. To obtain the full benefits of the new powers conferred on them, effective coordination of the work on air pollution by neighbouring Authorities should be established.

There have been, of course, for many years regional committees on which neighbouring Councils and, in some cases, other interested parties are represented. Their function is mainly to advise on the routine collection of test results from measurements of atmospheric pollution. The advantage of this cooperation lies in the ability to plan the pattern of distribution of the available instruments, see to their regular inspection and maintenance and assess the results of the observations. It would be a great step forward if the work of these committees were to lead to organizations of a more executive character so that the provisions of the Clean Air Act could be met on a regional basis.

Perhaps the best example where a scheme of " combined operations " should be established is London. In my opinion the whole of Greater London should be served as regards air pollution work by a body which will be empowered not only to advise on the initial steps of designating areas for smoke control, but will thereafter supervise the control itself.

Unless some such scheme is evolved and put into effective uniform operation, some of the more enlightened boroughs may share the experience of the City of London which has made itself completely smokeless—admittedly under special conditions of types of premises and population—but suffers from the inflow of polluting matter from outside sources.

The scheme which I envisage would entail planning the initial selection and adoption of suitable areas, preferably contiguous, and the chronological order in which others should be added. It would not be restricted to the establishment of the control areas, but would involve a continuing organization being set up for coordinating methods of control and watching their effects.

The peculiar combination of 103 Local Authorities which administer 700 square miles (448,000 acres) of built-up Metropolitan London will pose some awkward problems, but a good-neighbour policy, needed surely nowhere more than in the matter of air pollution, will find a solution to them.

The Metropolitan Boroughs' Standing Joint Committee has already taken some action to coordinate smoke control by recommending constituent Councils to consider conditions with a view to designating smoke control areas. Perhaps encouraged by this recommendation 35 London Authorities have taken active steps relating to more than 13,000 acres and nearly 100,000 premises, as shown in detail in Table 2.

Although the total acreage shown in Table 2 is only a small fraction (3 per cent) of the Greater London area, it indicates the willingness of one third of the London Authorities to make a start with smoke control. There are also signs that the value of coordination is appreciated. Of the six Boroughs bordering on the City of London—now a smokeless enclave—five have Orders confirmed by or notified to, the Minister.

TABLE 2

Smoke Control Areas in Greater London during Period ended 31st July, 1958

	Areas	*Acreage*	*Premises*
Smoke Control Order confirmed	13	2,542	14,548
Submitted for confirmation but not confirmed	14	2,825	14,977
Proposals notified to the Minister	34	7,167	48,100
Smokeless Zones and Smokeless Areas under Local Acts	2	682	17,992
Local Authority Housing Estates made or to be made smokeless by tenancy conditions	4	182	1,527
	67	13,398	97,144

Several Boroughs in West London—Fulham, Hammersmith, Willesden—have formed a Liaison Committee, together with Acton, Barnes, Brentford and Chiswick, outside the LCC area. As the outcome of this cooperation there will be within 10 years a clean air barrier stretching north and south across West London.

Dark Smoke

Whilst the control of domestic smoke is left to the good sense of local Councils at times of their own choosing, the emission of the dark variety—usually industrial—is, with certain closely defined exceptions, already and everywhere liable to heavy penalties.

The attitude of industry to the new legislation marks a radical reversal from that adopted in the past towards air pollution in general and towards the Society in particular whose leaders were regarded as cranks or incompetent enthusiasts.

A change came about when a Technical Committee was set up in 1946, of which I had the privilege of being elected as the first Chairman. Industry began to take the work of the Society seriously and to cooperate in a helpful spirit.

Compared with its opposition to the Smoke Abatement Act 1926, the following quotation from the submission of the Federation of British Industries to the Beaver Committee is illuminating:—

" In principle the reduction of atmospheric pollution has the entire support of the Federation. Industrial smoke emission should be reduced to the lowest practicable limit consistent with technical and economic considerations, and the Federation would support any effort designed to achieve this."

From the foregoing one may justifiably conclude that the Clean Air Act will bring to an end the mutual recriminations of domestic and industrial smoke producers, the pot calling the kettle black. The Act holds the balance fairly between the two, and, anyway, in the not too distant future smoke will be on the wane, and there will be only a small minority of recalcitrant offenders to be subjected to the full rigours of the Law.

The Technical and Scientific Aspect

We are all well aware that an Act of Parliament cannot become effective unless the means of implementing it are available and practicable. Policing alone cannot achieve the objective, and even the police has nowadays to go in for forensic science. The complexity of the phenomena of air pollution calls for intensive and—equally important—coordinated research for the solution of the many problems it presents. Let it be said at once that the Clean Air Act does not make any technical demands which cannot be fulfilled with present knowledge and experience, but the Act was drafted for the purpose of eliminating only the grossest forms of air contamination, leaving some of the more intractable problems for further consideration.

As in every activity of modern life, scientific research and practical development of its results are of the utmost importance and cannot be disregarded by the administrator. In fact, the Act authorizes Local Authorities to undertake or contribute towards investigations and research relevant to the problem of the pollution of the air.

RESEARCH

In my address to last year's Conference I described the primary material sources of air pollution. I shall now deal with the researches needed to confirm the facts stated and the opinions expressed, both in regard to the working of the Clean Air Act and with a view to the study of pollutants for which the Act does not expressly legislate.

Smoke

There is a large body of research organizations, professional Institutes, and technical departments of industrial firms engaged on studies of fuels and their combustion. The need for appliances, both domestic and industrial, complying with the relevant requirements of the Act, will be a sufficient incentive for them to improve existing appliances, devise new types and carry out fundamental research on combustion.

Smokeless Fuels

Methods for the manufacture of smokeless fuels have been practised for many years, but on a very restricted scale. Research and development should be directed to the production by the carbonizing industry of coke which is readily ignitable and tolerably free from incombustible matter. The advantages of low-ash coal for carbonization have been demonstrated in the past and may be enhanced by newer methods lately being developed. The realization of these advantages depends on the availability of supplies by the National Coal Board of thoroughly cleaned coal. This problem calls for economic rather than technical research. This should be done, for, with all the gas industry's new developments—complete gasification of coal and oil, using tail gases from petroleum refineries and importation of liquid methane—carbonization of coal will be practised on a major scale for a long time to come, not least for the purpose of supplying smokeless solid fuel.

Grit and Dust

The Clean Air Act does not prescribe quantitative limits of the permitted concentration of grit and dust in chimney gases, for two good reasons. We are still waiting for a reliable, all-round method of measurement, and dust concentration has little meaning without knowledge of the total weight emitted. Hence we are enjoined to use any practicable means to minimize the emission.

Here research is required firstly for finding reliable methods of measurement and secondly for improving dust arresting plant. It must be considered that the quantity of dust slipping through a large electrostatic precipitator working at the highest efficiency at present achieved will be of the order of 10 tons a day.

A line of research to be pursued is to identify flue dust with individual constituents of coal from which it is derived. Previous investigations indicate a close connection with the natural dust in coal. If coal were supplied in de-dusted condition the fly-ash in flue gases to be arrested would be greatly reduced. The formation of grit by aggregation of the more fusible ash of natural dust should also be investigated. These researches have become more urgent with the increase in the production of small coal in which the natural dust is concentrated.

Sulphur

There remains the sulphur problem. It sets the researcher some intricate questions. The weight of sulphur dioxide discharged into the atmosphere is more than twice that of smoke, grit and dust combined. Although sulphur compounds in the air are in quantity and virulence more damaging to health and property than any other pollutants, they were not dealt with in the Clean Air Act by reason of our lack of adequate knowledge of their causation and behaviour, and the slow development of generally applicable methods of dealing with them.

An obvious method of reducing the quantity of this pollutant is the elimination of at least part of the sulphur from the fuel before it is burned. In the case of coal this requires development and application rather than novel methods. Investigations on de-sulphurization of fuel oil are believed to be on the research programme of some oil companies. The need for a satisfactory solution is great in view of the high sulphur content of refinery residues.

The economics of sulphur removal from both coal and oil should be studied closely so as to ascertain a fair balance between additional cost and benefits gained.

An objective of the highest importance is the elucidation of the mechanism of oxidation of SO_2 to SO_3 which latter on combining with water forms sulphuric acid.

A small portion of the sulphur in chimney gases is always in form of SO_3, particularly where the combustion temperature is high. Work on the neutralization of this SO_3 is already proceeding, mainly for the purpose of protecting the inner surfaces of the flues and chimneys from corrosion by acid attack.

As the large bulk of SO_2 is eventually turned into SO_3 and the resulting acid finds its billet in metals, stonework, textiles, soil and vegetation, and irritates the respiratory organs of man and beast, the mechanism of this oxidation calls for close and urgent investigation.

An impression has been gaining ground that SO_2 only becomes troublesome in the presence of smoke or other solid particles. The plausible explanation is that it is adsorbed on the surfaces in high concentration and converted to sulphuric acid. There is as yet not enough reliable proof of this theory, nor knowledge how SO_2 reacts with solids of different chemical composition, acidic, alkaline or neutral, such as are found in a flue dust mixture.

These investigations are in the domain of physical chemistry and their clarification will be of great help in work on the elimination of sulphur oxides from flue gases, and of equal importance in the biochemical study of the action of sulphur acids on the human and animal body.

Flue Gas Treatment

The much debated subject of flue gas washing certainly needs close and impartial examination. Many of the objections to it are based on *ex parte* statements unsupported by adequate scientific or economic evidence. Having been repeated often enough without scrutiny they pass into the technical literature as facts. There is much scope for an independent, impartial inquiry.

The surveys of the distribution of sulphur oxides in built-up areas could be usefully extended. It has been found, for example, that the rise and fall of sulphur in the air at St. Paul's Cathedral follows closely the sulphur emission from the old Power Station at Bankside, whilst that from the new Station where flue gas washing is in operation does not show such a correlation and is relatively small, although the fuel consumption of the new station is a multiple of that of the old.

The recent announcement that the old station will be demolished next year is welcome news.

Motor Vehicles Exhaust

More knowledge on the cause and prevention of objectionable engine exhausts is badly wanted. This nuisance is a challenge to the oil and motor manufacturing industries to step up their researches. They should be qualified for the task and they will reap the benefit of any improvements effected.

Measurement of Pollution

The original Atmospheric Pollution Research Committee embarked on a fact-finding scheme of measuring deposits from the air with a meagre number of instruments quite inadequate for a complete survey. However, a detailed analysis in restricted areas gave useful indications of the distribution of solid pollutants. Since then the number of observations has steadily increased and of recent years has grown by leaps and bounds. This is very commendable, but it may be asked whether we are not now suffering from a surfeit of numerical data which we are unable to digest.

Collecting routine test results is not true research. They are facts needed by the investigator for drawing conclusions and it is his job to interpret the observations. He can only do this satisfactorily in relation to a well defined and circumscribed area and with additional information on the topography of the land, configuration of buildings, pattern of fuel consumption, height of chimneys and—most important—corresponding micro-meteorological data. A good example is the Leicester Survey, 1945.

For one who was closely connected with the initiation of the scheme it is gratifying to have watched its growth to its present dimensions, but I do believe that some of the effort and money devoted to collecting a multitude of figures could be applied to more profitable investigations.

There is, of course, still much scope for evaluating the effects of the new legislation. This involves improving old and devising new measuring apparatus, and arranging testing stations judiciously to yield the most instructive pattern of results.

Application of Meteorological Data

To make the best use of the routine measurements they should be integrated with the corresponding meteorological observations. This is not an easy task, and much thought will have to be given to the elaboration of a workable programme. The first joint meeting in May 1958 of our Society and the Royal Meteorological Society has proved the desirability of intimate liaison between all concerned in the solution of the complex problems of air pollution.

Nuclear Pollution

Impurities containing radio-active matter discharged into the atmosphere will in future come within the orbit of pollution research. This is not the place to deal with what is now a subject of international discussion in the highest scientific quarters. Nevertheless, there are two points I wish to make.

First, radio-active matter whether natural or man-produced will be a useful indicator of conventional pollutants with which it has become associated. The ease with which it is observed and measured will help in tracing positions from which smoke, grit and dust is emitted into the air. Such information has hitherto entailed elaborate collection and chemical analysis.

The other matter concerns the effects of polluted air inside industrial plant. Steps are now being taken in some cases to protect the flue systems and chimneys of boiler and other furnaces from corrosion by acid in the combustion gases. A parallel to this is the experience with graphite moderated reactors, recorded in the Final Report of the inquiry into the accident at Windscale Pile No. 1 in October, 1957. It appears from the Report that quite small quantities of various contaminants, which can be deposited in the graphite of a pile from the air used to cool it, greatly enhance the rates of oxidation. Hence the temperature may rise above the safe limit and become uncontrollable.

The Role of the NSCA

Unquestionably much scientific and technological effort of the highest calibre must be applied to achieve the objective, clean air. The Society's constitution does not provide for entering the field of active research of the kind indicated. Nor do its resources allow it to contemplate such costly ventures. The services of many branches of science must be enlisted. The formulation of a programme for coordinating and integrating such work is in itself a formidable task which may well be undertaken by the Clean Air Council.

In a matter which touches every citizen, even ministerial authority will have to be supported by public opinion, and I submit that our Society has proved its ability to provide this service. It has succeeded by its sustained efforts to make the general public aware of what has to be done to exorcize a national evil. It will do equally useful work in the future in the fields of education and propaganda, by its publications, by stimulating discussions in London and the Provinces. Indeed, the Society has become a central clearing house for information on all aspects of air pollution and its abatement. What the Society now needs is an appreciably increased supply of funds to meet the new and heavier duties falling on it.

Clean Air is on the way, but it has not yet arrived.

Industrial Aspects of the Clean Air Act

(1) THE CONTROL OF DARK SMOKE EMISSIONS

by

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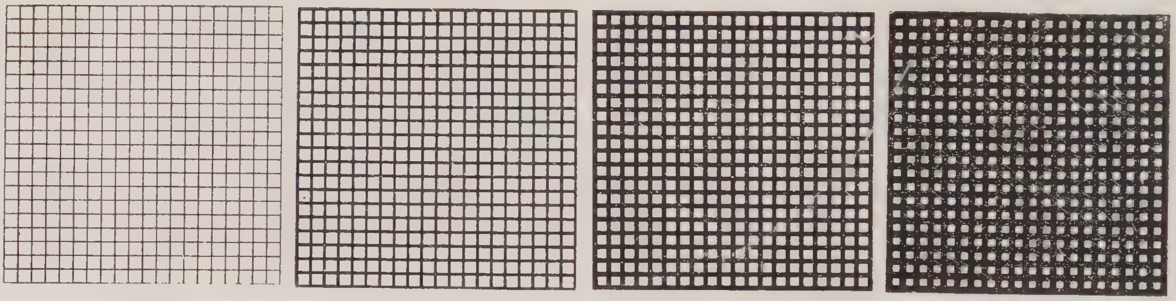

Introduction

ALL the provisions of the Clean Air Act, 1956, have now come into operation, including the regulations relating to the permitted time periods for dark smoke emissions from chimneys of buildings. Also an excellent pamphlet in the form of a *Memorandum on the Industrial Provisions* (*Clean Air Act, 1956*) has been published by the Ministry of Housing and Local Government.

This Memorandum is of outstanding value to all local authorities, and can be recommended for the attention and guidance of all industrial managements and fuel users.

The duration and density of smoke emissions as enacted in The Dark Smoke (Permitted Periods) Regulations, 1958, may not reach the standard of perfection desired by idealists. It may seem regrettable to legislate for black smoke in the year 1958, and to provide quite formidable defences, but it is obvious that the pattern the Minister has created, is woven from the threads of recommendations made in the Beaver Report, reinforced by findings of the Technical Committees of the British Standards Institution, and the assessment of representations made by industry and local authorities at the meetings with the Ministry when the draft regulations were being formulated.

The Minister and his advisers have produced an instrument of legislation which recognizes that under certain circumstances dark smoke from the combustion of bituminous fuel is unavoidable, and that such smoke should be limited to definite time periods.

Responsibility of Local Authorities

With the exception of the schedule processes controlled by the Alkali

Inspectorate of the Ministry of Housing and Local Government the responsibility and duty of ensuring the implementation of the new legislation appertaining to the control of dark smoke emissions in England and Wales is placed directly on all local authorities, and the question remains, especially in the so-called black areas, will they accept this responsibility and all that it entails? Or, will other urgent matters such as housing, redevelopment, education, and the proposed reorganization of local government receive priority, and so allow the serious position as revealed in the Beaver Report para. (114) in relation to smoke abatement administration to remain a minor part of local authority activities?

Results Obtained From the Implementation of Legislation

Whilst recognizing that the Clean Air Act provides ample opportunity for the requirement that all new furnaces should be capable of being operated without contravening the provisions of Section 1 it is my opinion that the full implementation of the legislation by local authorities requires: (*a*) constant supervision for contraventions, (*b*) co-operation with offenders through the strength of enforcement, (*c*) the determination of the contraventions through legal proceedings, if co-operation fails.

The following tables extracted from departmental records support this opinion. It should be noted that the observations refer only to the emissions of black smoke from industrial chimneys and the results which followed from the enforcement of byelaws under the Public Health Act, 1936, procedure. The byelaws prescribed that the emission of black smoke for a period of three minutes in the aggregate within any continuous period of thirty minutes from any one chimney (other than a private dwelling house) shall until the contrary is proved be presumed to be a nuisance.

Thus indicating the trend of the overall reduction in the average smoke emissions which was effected by the service of abatement notices by the local authority and thereby an improvement in the pollution of the atmosphere. During the period under review, however, it was necessary for the local authority to institute legal proceedings in 19 instances for disobeyal of the abatement notices whereby penalties were imposed and magistrates orders granted.

Co-operation Through Enforcement

The 233 chimneys which were subject to abatement notices served various types of boiler and trade process furnaces, of this total 164 (70 per cent.) served hand fired coal burning furnaces, 46 (20 per cent.) served furnaces coal fired by mechanical means, and the remaining 23 (10 per cent.) served either oil or coal producer fired furnaces, so proving the contention that the hand fired coal burning furnaces are the greatest offenders in regard to industrial smoke emissions.

From the correspondence that arose out of the service of the abatement

Routine District Inspections

Year	*Chimneys observed*	*Contraventions of Bye-laws*	*Total black smoke noted*	*Average per 30 minutes*
1955	2764	83	909 mins.	10·95 mins.
1956	3523	76	792½ ,,	10·43 ,,
1957	5133	74	898½ ,,	12·14 ,,

Observations following the Service of Abatement Notices of Contraventions

Year	*Number of chimneys*	*Number of observations*	*Total black smoke noted*	*Average per 30 minutes*
1955	83	412	498 mins.	1·21 mins.
1956	76	317	296 ,,	·93 ,,
1957	74	427	220 ,,	0·513 ,,

notices, various schemes were proposed by 135 firms. The advice of the local authority was sought and the remedial measures suggested were adopted.

The following table summarizes the proposals received:

Year	*Stricter supervision by managements*	*Changes in fuel effected*	*New plant and equipment*	*Estimated expenditure*
1955	22	10	14	£23,000
1956	26	3	7	£18,000
1957	24	8	9	£ 3,450
	72	21	30	£44,450

In regard to changes in fuel, electricity, oil, coke, and gas have been substituted for bituminous coal. The new equipment consisted of the replacement of old plant, mechanical stoking arrangements, oil fuel burning installations, boiler plant and process furnace instrumentation, and smoke density meters, thus showing the extent of co-operation which can be brought about through the strength of initial enforcement.

The Dark Smoke (Permitted Periods) Regulations, 1958

At some time or other opinions have been voiced on the short-comings of the Public Health Act legislation for dealing with smoke nuisances. The main points of criticism have been:

(*a*) The roundabout method of enforcement procedure.
(*b*) The qualified exemption given to certain processes by Section 109 of the Act.
(*c*) The absence of a definition of the term " black smoke."
(*d*) The difficulties of establishing evidence of a nuisance.
(*e*) The wide scope of defence available in the case of prosecutions.

Under the Provisions of Section 1 of the Clean Air Act, 1956, and the Dark Smoke (Permitted Periods) Regulations, 1958, the criticisms (*a*), (*b*), (*c*), (*d*) and to a considerable degree (*e*) have been removed, and Section 16 of the Act which refers to smoke nuisances amends in some important respects the procedure under the Public Health Act, 1936.

The shades indicated on the Ringelmann chart are now the standards by which excessive emissions of dark smoke can be dealt with. The nuisance procedure has been removed; such emissions are contraventions of the Clean Air Act, 1956.

" Black smoke," means smoke that would appear to be as dark as or darker than shade 4, and " dark smoke," means smoke that would appear to be as dark as, or darker than shade 2. Copies of such charts and instructions on their use are available through the British Standards Institution, Park Street, London, W.1, and Messrs. Charles Griffin & Co. Ltd., Drury Lane, London, W.C.2. The Minister has not yet prescribed by regulation any method of ascertaining whether smoke is dark smoke within the definition of the Act. Of course, if such regulations are made the carrying out of the procedure as prescribed would be essential as evidence of proof in any legal proceedings, however, in the absence of such regulations and for guidance of the court the evidence of the observations recorded by an inspector experienced in the use of the chart may be offered and accepted. It is essential that all local authorities should ensure that their authorized officers should be fully experienced in the use of the chart and the shade numbers. Some inspectors have used the Ringelmann chart since the beginning of the year for observation purposes during routine inspections, with the result that they have become familiar with the chart and the recording of the density of smoke emissions by ordinary visual methods.

With the coming into operation on the 1st June last of the Dark Smoke (Permitted Periods) Regulations, it is certain that the administration and enforcement of the provisions by local authorities will place a considerable responsibility upon them, if the regulations are to be effective, and whilst nothing in the regulations authorizes the continuous emission of dark smoke caused otherwise than by soot blowing for a period exceeding 4 minutes; or the emission of black smoke for more than 2 minutes in the aggregate in any period of 30 minutes, the administration of the provisions in Section 3 Sub-section (1) and (2) of the regulations which relate to the sliding scale for the permitted periods of emissions of dark smoke from any chimney for not longer than 10 minutes in the aggregate in any period of eight hours, or 14 minutes in the aggregate if soot blowing is carried on and rising to 29 minutes and 41 minutes respectively in the case of dark smoke emissions from a chimney serving four or more furnaces will be quite impracticable to administer in many areas.

I wonder how many local authorities have the staff available or even the time to spare to ensure the carrying out of such enforcement duties over these extended periods?

Soot Blowing: Dark Smoke Emissions

The limits imposed by the regulations when soot blowing operations are taking place appear reasonable. The following table is a typical example of smoke observations carried out on boiler plant chimneys to assess the emission of dark smoke noted during soot blowing operations. It should be noted that the chimneys did not serve boiler plant of electricity works or similar boiler plant rated high enough to come within the jurisdiction of the Alkali Inspectorate and the emissions of smoke noted did not contravene the regulations.

The frequency of soot blowing depends on the type of fuel in use and the dark colour of the smoke emitted is mainly due to the micronic soot or grit particles detached from the heating surfaces. No outside observer can tell whether the dark smoke emitted is from the incomplete combustion of the fuel, or soot blowing, therefore, it is obvious from a practical point of view, that in the case of all large boiler plants where soot blowing takes place, the records should be made readily available to the local authority. It may be considered that more frequent soot blowing would reduce the emissions of dark smoke, but in large plants soot blowing more than once a day tends to become uneconomic practice and is, therefore, not looked upon with favour.

The regulations will, however, leave it quite open for soot blowing to take place during the daylight hours and so relieve the night shift of this work, for it is generally carried out surreptitiously when darkness falls. In small boilers such as the Economic type where soot blowing takes place by steam lancing or any other means, such operations are generally carried out without contravening the regulations, but it is as well to remember

Type of boiler	One water tube chain grate stoker. Rating 35,000 lbs. per hour.	One water tube chain grate stoker. Rating 35,000 lbs. per hour.	One water tube chain grate stoker. Rating 35,000 lbs. per hour
Number of observations	Six (30 mins. period)	Six (30 mins. period)	Six (30 mins. period)
Smoke noted during steaming operations	Constant brown haze	Haze only intermittent	One minute of Ringelmann No. 1
Average dark smoke noted during soot blowing	3 minutes R.2 1 minute R.4	2·5 minutes R.2 1 minute R.4	2 minutes R.2 2·5 minutes R.4

that even in the case of these comparatively small boilers if soot blowing takes place during the period of observation the additional permitted time period as allowed by the regulations will apply.

Dark Smoke Control—Railway Engines

The Dark Smoke (Permitted Periods) Regulations, 1958, apply to the emissions of smoke from railway locomotives generally and not only to those operated by the British Transport Commission and the provisions in earlier Acts which proved so ineffective for the abatement of smoke from railway engines are repealed.

From the observations maintained on individual coal fired locomotives operating at engine sheds, goods sidings, and stations, the emissions of black smoke that have been noted have rarely contravened the new limits of two minutes in the aggregate over a period of thirty minutes. It is when a number of locomotives are standing under steam on departure roads from the locomotive depots that a greyish smoke pall often occurs. This smoke being emitted at a comparatively low level does not disperse with any great rapidity and can be a considerable nuisance to the local inhabitants but assuming that no individual engine emits smoke of a greater density than 1·99 of the Ringelmann chart no powers are available under the Clean Air Act, 1956, to deal with such a nuisance.

Several features in furnace design of locomotive boilers such as the deflector plate, brick arch, and the blower all contribute towards improving the combustion of coal in the furnace and when an engine is standing under steam the discriminating use of the blower will keep the smoke emission down to the permitted density.

Temporary Exemption Certificates

Section 2 (2) of the Act recognizes that it may not always be possible to prevent the emission of dark smoke from chimneys until alterations to the existing plant or furnaces have been carried out and the provisions of this Section enable a local authority, if they think fit in suitable cases, to issue a certificate of temporary exemption from the provisions of Section 1 of the Act. This certificate may be given for the period of a year from the date of issue or for such shorter periods as may be specified. Certificates which expire after one year can be renewed, but no certificate will remain in force after the 4th July, 1963.

This system of certification is new in smoke abatement legislation and provides an excellent opportunity, if used judiciously, for the control of dark smoke from existing chimneys serving boiler or industrial plant.

Though the results are not immediate it is obvious that when discussing the grounds of the application with the applicants co-operation can be established whereby the undertakings that may be given will be such that, within a reasonable period of time the adaptations proposed will ensure that the likelihood of future contraventions are limited.

Conclusion

The control of dark smoke can be achieved if the representatives of local authorities accept the responsibilities that the full implementation of the Clean Air Act, 1956, involves. The common practice of waiting for smoke nuisance complaints from the public before action is taken is over. All areas should be subject to constant inspection and contraventions should not be allowed to persist.

In many cases the co-operation of the owners or occupiers of the premises is readily available once their attention is drawn to such contraventions and persuasion rather than compulsion is the answer, on the other hand there is sometimes a hard core of resistance to be overcome and in such cases the local authority should ensure that the enforcement of legal proceedings can be carried out. If the representatives of local authorities who are in fact the policy makers do not accept the responsibilities placed upon them by the Clean Air Act, 1956, then I suggest that one of the ideals of this Society "To encourage the adoption of methods to reduce and prevent atmospheric pollution," will be of no avail.

In this paper I have not ventured to include comments on the control of dark smoke from vessels, my views mainly have been confined to the control of dark smoke from industrial furnaces.

(2) GRIT AND DUST EMISSION: METHODS OF PRACTICAL CONTROL AND REGULATIONS

by

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Introduction

THE particular aspect of the general problem which I was invited by the Conference Committee to introduce at this session was that of methods of practical control of grit and dust emission to meet the requirements of the Clean Air Act, 1956. It is to this aspect that I shall confine myself and will omit any attempt to discuss the technical details of design of the equipment and appliances which could be employed by potential users. Such aspects I shall leave to the attention of those who are expert in such details and it may well be that some reference to special equipment may be enlarged upon in subsequent discussion. I realize that the primary intention of the Committee is to endeavour to direct the attention to it, of those delegates and officials attending this Conference who have not heretofore done specialized work in the subject, and to whom the administrative procedure to be adopted under the Act in connection with dust emission could be of immediate use and application.

This aspect of nuisance and danger, while quite evident for many years prior to the past war, was not so prominently within public and official concern as it has become in the post-war era. Official attention was first directed to the subject, I think, about 30 years ago as it is within the author's recollection that it was at that time that technical discussions began on the consequence of dust and grit emission due to the increasing development of pulverised fuel burning. In modern combustion plant practice the control of grit and dust emission receives major attention equally with potential smoke emission and most large and many medium capacity plants are equipped with suitable types of mechanical arrestors. Many plants of power station size are equipped with electro static precipitators.

Where dust and grit emission occurs

in densely populated districts, either domestic or industrial, the results are immediately apparent and complaint widespread. In the case of large process plants where the spent gases are not confined as closely as in normal fuel passes or flues, the elimination or reduction of dirt and grit presents a more complex problem and, notwithstanding the general acceptance of the possibility or existence of dust emission, very many plants are not equipped with any form of arrestation at all. In many such processes the problem of concentrating the plant gases, together with the erection of special directional and connecting trunking, can and does present problems. It may well be that changes in fuel type and/or grading are indicated and supply difficulties can be encountered in this latter connection.

It must be repeated that grit and dust nuisance is more intolerable than smoke and is a source of immediate danger to eyesight and respiration, not to mention the possibility of fire hazards in connection with certain plants and processes.

In many instances dust nuisances arise from process causes as distinct from combustion. In the majority of such cases, the requirements of the Factory Acts govern such emission and they are so often amenable to suitable reduction. Every effort should be, and will have to be, made to have salutary measures adopted and the nuisance and danger abated and prevented. Expenditure, space and operational costs have been and are so frequently the deterrent and influencing factors in the failure to adopt a suitable means, but the author feels that if the full intent of the relevant sections of the Clean Air Act are to become effective in the reasonable future, then these considerations cannot for long be accepted for such reluctance. The sections of the new Act concerning dust and grit are quite specific but there is no doubt that the practical administration and implementation of the provisions of the statute will take time, much ingenuity and not a little coercion.

Clean Air Act, 1956

In the onerous and involved deliberations of the Beaver Committee, a very exhaustive survey was made of the problem of dust emission and the importance of this component of atmospheric pollution to that Committee is evidenced by the fact that in the succeeding Act, Sections 5, 6, 7, 8, 9 and 10 are devoted exclusively to dealing with the problem.

It is assumed that most of the delegates to this Conference, and certainly all those immediately and intimately concerned with the administration of the Act, will be reasonably familiar with the provisions and desiderata of these Sections. Even so, the requirements of these Sections might be restated with advantage to some. The Sections are quite specific in their statement and intention.

The drafting of Section 5 is explicit that grit and dust from furnaces shall be minimized and distinctly states that where a furnace is used to burn solid fuel or solid waste, either within or without a building, in any process involving the application of heat, the user shall employ all or any practical means that may be open to him for minimizing the emission of grit and dust from any chimney serving the furnace. Failure to do so is an offence.

The implied requirement of Section 6 is that new furnaces shall be fitted with plant to arrest grit and dust, particular reference being made to pulverized fuel and to plants which have a burning rate of one ton or more per hour using solid fuel in any other form, or even solid waste; such new plant must have been either approved directly by the local authority or at least been installed in accordance with plans and specifications submitted prior to its installation. In addition, such plant must be properly maintained and used. Failure to comply with this Section is an offence. Sub-section 3 of Section 6 enables the Minister to give special consideration or to issue a directive to a local authority with regard to the approval, or otherwise, to be accorded in special and difficult cases. In this connection also, under Sub-section 4, it is to be noted that direct appeal to the Minister may be made should the appellant be dissatisfied with a decision of the local authority.

Section 7 provides that the local authority may, by notice in writing, direct the occupier of the plant, because of special circumstances which may exist, to take steps to ensure the measurement of grit and dust emitted from such plant by the installation of measuring and recording instruments and informing the said authority of the results. Failure to comply with such a directive would constitute an infringement of the Act.

Section 8 requires that special information about furnaces used and fuel consumed shall be supplied to the local authorities after written request served on the plant occupier. This information would be for the benefit of the controlling authority in so far as dust and grit emission is concerned. Failure to conform here would also be a contravention of the Act.

Section 9 defines that the four preceding Sections shall apply to outdoor furnaces as they would apply to boiler furnaces or ovens in a building and will enable the local authority to maintain effective control over the dust emission from such out-door furnaces, similarly as in the case of indoor plant, even to dealing with purely temporary installation if necessary.

Section 10 relates to the heights of chimneys and the provisions of the Section deal with proposals or plans to erect chimneys connected with such plant. The authority can accede or withhold sanction unless they are satisfied that the height of the chimney " will be sufficient to prevent, so far as is practicable, the smoke grit, dust or gases from becoming prejudicial to health or a nuisance ". It is to be noted that in this connection the details of the surrounding locus are taken fully into account. Where plans under Sub-section 3 of this Section 10 are rejected by the authority, the person interested in the project may make direct appeal to the Minister. It is also to be noted that the provisions of Section 10 do not apply to " the erection or extension of a generating station as defined in the Electricity (Supply) Act, 1919, other than a private generating station as so defined ".

I have dwelt at some length on the aspect of the preceding Sections dealing with dust emission, to enable those authorities and officials involved in such control to be aware of the importance and purport of this aspect of the Clean Air Act and to indicate clearly the powers which are vested in them, to carry through the statutory work which will be necessary to ensure effective administration of solid pollutants. It will be apparent that the powers vested in local authorities to that end by the Act are quite comprehensive.

Relevant Section of Clean Air Act, 1956

In the control to be exercised over the emission of dust and grit, very important factors in connection with such particulate material are the specific gravity of the dust discharged, the sizing and whether the chimney or shaft is of suitable location or of sufficient height to ensure an adequate dispersal of the residual material to be carried away.

It is usual to refer to the size of dust and grit as being so many microns, in short, micronic dimension of the dust is a measure of the mass of the particles. A micron is defined as being particulate matter which has a linear equivalent of one millionth of a metre, or one thousandth of a millimetre, or 1/25400 of an inch. The sizing of a particle in industrial dusts varies from less than one micron to 300 microns or over. In speaking of dust, it is the practice to refer to it as containing a percentage below a given micronic size and here the sizing refers to the diameter of the particle. When dealing with grit, i.e., in the coarser range, an analysis of the sizing of the constituents is obtained by sieving, either by means of British Standard or a " Tyler " size sieve and this sieve-sizing is given in place of, or it may be together with, micronic size. To enable these almost microscopic dimensions to be visualized, it could be stated that a particle of sea-shore sand will vary between 100 and 200 microns in diameter. A commercial steel pin point may vary between 20 and 30 microns in diameter, or it may also be noted that with adequate lighting the smallest black particle on a white ground visible to normal human sight is about 10 microns in diameter. Chemical fumes generally consist of particles of less than one micron and, as a matter of interest, it is stated that tobacco smoke is of a particulate size of less than half a micron.

In the finer ranges of dust, say below 50 microns in size, methods other than sieving are made use of: one such method being that of elutriation. In this method samples of dust are subjected to rising and increasing currents of air or water. By this medium particles of known dimensions are raised from the sample in ratio proportional to their weight and mass and the velocity of the air or water being used for elutriation. By varying the speed and kinetic impact of the air or water separation into differing micronic size is effected.

The sizing of the dust particles being liberated from a particular source of pollution will also play a major part in the distance they will travel from that source. The larger or coarser grits will be deposited adjacent to or near the source of pollution while as the size of the particles decreases then they will travel very much further afield, assuming that wind velocity is constant; the latter, of course, is a factor which varies according to high ceiling, topography and ground resistance.

According to a paper by P. E· Arlidge on the " Application of Dust Collecting Equipment for Industrial Plant," it is shown diagrammatically that from a chimney 75 feet in height and with a constant 5 m.p.h. wind in standard air and based on Stokes Law, experiments had shown that there was fall-out of 150 micron-sized particles at 100 feet distant from the base of the stack, with intervening ranges down to the finer range of 20 microns which was deposited at a range of 1·185 miles.

For those members of this Conference who are further interested in methods of dimensional measurement of dust and grit, many interesting papers and addresses on the subject are available under the aegis of various authorities. They could, for instance, be referred to the joint paper by England, Crawshaw and Fortune on the subject of " Dust Deposition in the Neighbourhood of a Power Station," which was given in the September, 1957, issue of the Journal of the Institute of Fuel.

Examples of Plants and Processes coming within the scope of the Clean Air Act Regulations

The range and diversity of steam raising and process plants that may and do give rise to dust emission are numerous and diverse in design and application. In straight steam raising, the size and output of the plants may vary between the range of power station practice to that of even the individual shell-type boiler. There is this feature in common in that the furnace space and connecting flues are confined and draughted to an individual chimney or chimneys. In this way there is, within the limits of design, a possibility of adapting one or other of the accepted and prevailing types of mechanical type arrestors or incorporating some of the more modified methods of dust extraction.

In the case of process work involving combustion and heat application in its many wide forms, and also in those purely industrial process operations outwith the sphere of combustion, many instances arise where the effluent dust-laden gases are not so confined and we are faced with the problem of dealing with large volumes of free air and gases. In this latter category the efficient incorporation of grit and dust arresting methods and appliances is very often not an easy matter, and frequently where such plant or methods have been installed the ultimate efficiencies obtained are comparatively low.

There is again so often the problem of high temperature gases to be dealt with and this in itself can and does create very special problems in any of the categories mentioned.

In the above observations, examples of types of plant met with in every day industrial practice, and involved in more obvious dust emission could be cited the following. Steam raising practices, including water tube and shell-type boilers and larger sectional-type heating boilers. Within the metallurgical furnace and process range could be mentioned blast furnaces and varying designs of sintering plants, coke ovens and foundry cupolas, pottery kilns, brick kilns, chemical furnaces, both rotary and static, refuse destructors, including similar type incinerators. Under the heading of purely process operations without combustion, could be enumerated chemical fertilizer plants, etc., fuel and ore handling and conveyor plant, ash conveyors, sawmills, etc. In addition, there is the localized problems of dust from railway locomotives and also from servicing or running sheds.

Bearing in mind the comments made above regarding the adaptability and facility of application of dust arrestation methods to the varying range of plants encountered, it will be seen that a number of the major contributors to the dust menace do not lend themselves to methods of control. A number of makers of world-wide reputation of dust control equipment have devoted much time, energy and capital in intensive research work into the problems concerned with both the design and application of their products to many of the more complex problems connected with the incorporation of their units, and it can be said that very high degrees of efficiency are attainable. Efficiencies within a range of over 95 per cent are quoted.

Types of Dust Arrestors which may be installed

When a source or anticipated source of dust is known, a very approximate or precise analysis of it is determined and that, together with the estimated quantity involved, will be indicative of the type of such arrestor plant which can be installed.

There are five main methods and types which may be made use of, these are:

(1) The settling or expansion chamber.
(2) The bag filter.
(3) The volumetric or multi-cell cyclone collector.
(4) The electro-static precipitator.
(5) The wet arrestor or scrubber.

There are combinations of these, together with gas-washing plants, working on both the open and closed cyclone principles. The intention of this latter method, especially in plants of very large size, is to provide means of gas-washing and the reduction of sulphurous compounds. The process of dust elimination is merely incidental so I shall make no observations on this latter system.

The Settling or Expansion Chamber

The settling or expansion chamber is either a specially constructed insulated casing or an actual enlargement of the flue pass. Such an increase in capacity causes a reduction in the gas velocity. The carry over of dust in a flue space requires a velocity in the range of 30/40 feet per second and if such velocity drops to around 10 feet per second much of the coarser grit will fall out. With the introduction of hanging and standing baffles and in some cases with water sprays between the baffles, a further separation of finer particles will be achieved. With the use of such a method naturally high efficiencies are not realizable, but such a comparatively simple method does in many cases where such heavier grit is the actual source of nuisance, result in its abatement.

Bag Filter

This method of elimination is made use of principally in industrial processes and it is not adaptable where higher temperatures are involved, although with newer heat resisting materials being evolved the field of adoption is being extended. These fabric-type filters may be of surprisingly large dimension and can be as large as 36 inches in diameter by 30 feet in length. There are various methods of suspension in sealing and confining the gas stream. Shaking and rapping gears are made use of so that the bags can be kept clear, chokage being thus much reduced. They are also arranged in series so that change of flues may be effected. Other arrangements are that scavenging air, under pressure, can be directed in reverse in order to keep the filters clear. Surprisingly high efficiencies can be had with this type of separator, especially with fine dusts of the order of 5 microns and below. An efficiency of as high as 99 per cent is already stated by some manufacturers.

Volumetric or Multi-Cell Cyclone Collector

In one of the simplest forms of the volumetric cyclone collector, the unit is utilized for the dual purpose of induced draught and also separation. A fan rotor with suitably radially inclined blades revolves at high speed close to a cone which has an open trailing edge. The dust particles are acted upon by centrifugal force and are thrown against the face of the cone travelling to the outer open trailing edge and are passed into the receiver. In another design, by a very well-known northern maker, embodying the same principle, the radial vanes are statically set and may be either in an up-draught or down-draught gas flow. The negative pull of a separate induction fan imparts a high velocity to the gases and again centrifugal force acting upon the particles projects them to the outer sides of the surrounding casing and they pass around the periphery of the outside casing to the receivers. In a further development of the cyclone principle, the multi-cell type is made use of and a series of static vanes in a multiple number of small trunkings replaces the larger area of the previous types mentioned. Necessary energy is imparted to the gases by means of a high velocity induction fan and in their passage through the tubes, either as vanes or spirals, the dust flows to the outer casing of the tubes and enters the receivers for disposal. The draught losses through these types are comparatively low and are within a range of not more than 0·25 inches w.g. to a higher w.g. loss of one inch. Separation efficiencies vary between 75 to 90 per cent. In addition, certain such types of separators may be used on a multi-stage arrangement and the successive separation of a proportion of the gases through each stage results in a higher ultimate efficiency.

Electro-static Precipitator

The highest possible dust separating efficiency is achieved by either electro-static precipitation or actual wet-washing of the gases. These electro-static precipitators are capable of separation efficiencies of upwards of 95 per cent and can actually be used to separate particles coming within the smallness of the fume range. The gases pass through the units at very low velocity of the order of 3 to 5 feet per second and at this low velocity the larger particulate matter settles out, largely by gravity and partly by the action of the electro-static field within the appliance. The smaller and smallest dust is precipitated almost entirely by electro-static influence alone.

The modus operandi is that the dust and grit-laden gases are caused to pass between a series of tubular electrodes, one of which is of much smaller diameter than the other and carries a high potential discharge of electrical current; the other electrode is of a much larger surface contact and is the lodgment area for the dust from the gases, which dust, owing to its ionization by high voltage current, is attracted by the receiving surface of this second electrode. The latter electrode is earthed and the ionized dust adheres thereto. The electrical charge is neutralized to earth. Suitably arranged rapping and vibrating gear causes the earthed electrode to precipitate the dust into receptacles arranged beneath. The gas resistances in this type of installation are of an order of under one inch w.g. Mechanical arrestors may be used in conjunction with electro-static precipitators and are placed in the gas stream ahead of these latter, the object being to reduce the loading on the electrostatic units by prior separation. In this way the terminal efficiency is much increased and figures of up to 99·9 per cent are quoted. The capital cost of electro-static precipitation is very high and, in addition, large space requirements are the rule. These two factors almost preclude the use of such a system except in plants of the largest size and up to power station magnitude.

Wet Arrestor or Scrubber

The use of water in the entrapping of dust is one of the earliest forms of control. It is on record that the first practical application of the wet method was as early as the beginning of the 18th century and was employed in the pottery districts. Generically the types of such wet scrubbers or arrestors are in three categories with modifications in each case—the spray type, absorption ring type and the film type. A typical unit consists of a tower or casing which is fitted with a series of plates or louvres through which the scrubbing water cascades. Directional flow baffles are placed at the bottom, the dust-laden gases entering either at the bottom or sides and directed up through the cascading streams of water or liquor and in this way a high degree of clarification of the gases is obtained. In the employment of this form of dust removal it is, of course, essential that there must be a generous supply of water available, otherwise the cost of water and pumping power may be considerable and the system would be uneconomical. The water is recirculated from the catch traps after sedimentation and arrangement is made for making up loss. Some such arrangements work in conjunction with cyclones and this has certain advantages. For small plant operation and where only coarser grit is the problem, simple arrangements of either annular sprays or umbrella sprays within the chimney can be suitably arranged and these may be sufficiently effective. Such elementary arrangements are, of course, hardly accessible and excessive corrosion could be a problem.

Electrical Generating Stations

In the field of dust and grit removal from the effluent gases, either from power production or from industrial processes, it has already been mentioned that most of the prominent combustion engineering equipment makers and other interested authorities have given much time and research to the problem and probably none more so than the Central Electricity Authority itself. This, of course, will be very apparent having regard to the magnitude of the operations at so many points controlled by that Authority. I have already referred to one such comprehensive survey, being one of four papers on " Dust Deposition and Atmospheric Pollution," given before the Institute of Fuel in 1957.

It could be said that the advent and continuous use of pulverized fuel firing necessitated the focusing of attention on the early problems that did exist and the potential problems that might subsequently arise, and it would be true to say that the concentrated and sustained efforts of the Authority in this direction have been very successful.

Railways' Operation

Under the legislation available, both local and general, prior to the inception of the Clean Air Act, 1956, the problem of dust emission from steam locomotives was fully recognized and under the new statutory regime it is still recognized as such.

Investigations of the Beaver Committee brought it to the conclusion that 1/7th of the smoke discharged to the atmosphere in this country was due to locomotive practice. Having regard to draughting conditions involved on both passenger line running conditions, and general shunting or marshalling operations, it could be assumed that the proportionate dust contribution by the railways is even greater than the above assumption.

Sporadic attempts have been made in this country, in America and on the Continent to devise some practical form of dust arrestor. Until the present this has not been successful and from the necessity for sustained availability and operation, it would appear that success is not likely to be achieved. It can be agreed with the Beaver Committee, and all other authorities, that the only salutary solution to the problem will be the ever increasing change-over to electrification and dieselization.

Shipping

While the provisions of the Clean Air Act apply essentially to shipping in the same manner and to the same extent as applied to stationary plants, the probability of extensive dust nuisance from vessels, often in confined waterways, is remote because now the majority of shipping, both large and small, is oil-burning or powered by diesel machinery.

Instrumentation, Measurement and Recording

Measurements, estimations and recordings, in connection with atmospheric pollution, have been standard practice in this country for many years. A number of local authorities have been engaged in this work on a systematic basis since as early as 1914. In those earlier years the results were correlated and co-ordinated by the Air Ministry but since 1927 such work has been under the collation of the Fuel Research Survey of the Department of Scientific and Industrial Research as the Central Authority. The aspects under survey are those of smoke density, dust precipitation and sulphur dioxide concentration. For those purposes there are, shall we say, standard instrumentation. The subject matter of this address is grit and dust emission and I shall confine my observations on instrumentation to this aspect.

The precipitation of grit and dust from the air is estimated by the standard deposit gauge of very simple construction. The dimensions and design of such a gauge have been set down by the D.S.I.R. and at the present time approximately over 200 bodies representative of local authorities, industry and research make use of this somewhat arbitrary instrument. It consists essentially of a glass collecting basin of approximately 12 inches in diameter suitably supported over a capacious receiving bottle. The rainfall over a month is collected. This contains a proportion of solid deposited matter, mainly of dust and grit, which has been precipitated on dry days and which also has been scavenged down during wet weather. The collected water is analysed by chemists and with the other elements mentioned above, estimates are determined for the deposition of solid matter consisting mainly of coarser grits and finer dusts. The estimations are invariably expressed in tons per square mile. As the disproportion between the area of the collecting basin and the unit as a square mile, the results obtained are no doubt in many cases erratic but at least such an instrument gives a comparative approximation of the conditions existing in the collecting station locus. Such a gauge is readily influenced by site, prevailing wind drifts and surrounding sources of smoke and dust emission, both industrial and domestic. It is a useful instrument where conditions existing in given areas are reasonably static.

Over unit periods, i.e., from a single month extending, say, to 12 months where due to causes which have to be determined such conditions fluctuate and where pronouncedly heavier depositions are known or suspected over much shorter periods then use can be made of petri dishes.

Petri dishes are useful for short period observations but only in suitable weather conditions. They are not usable in wet weather nor under conditions of strong wind. Under these conditions they may readily overflow or have the contents actually blown out. The method is employed more for " snap readings " and in very localized areas which are subject to some immediate sources of nuisance. For direct estimation of dust transmission to a shaft or chimney where such emission is more or less concentrated, Whatman Thimble Filters used inside a suitable probe may be made use of. The sampling periods with this method are short, usually of about 15 minutes' duration at each point of the flue, chimney, shaft or actual confined building. This method is especially useful in determining the nature and character of particular dusts encountered in an area.

Administrative Procedure

If in a given area, district or immediate locality, it is known or suspected that a serious dust pollution condition exists, if the actual source of the emission has not been or cannot be visually determined then recourse has to be had either to a protracted test over a period with a series of standard gauges suitably located or else shorter or immediate tests have to be made by the use of the other instrument mentioned.

The pin-pointing of the source of an obscure dust nuisance, especially in an industrial area where there may be many points, plants and processes from which dust could be emitted, may be very difficult and protracted. As has been stated if an area is affected then a series of standard gauges, it may be as many as a dozen, would be required and these are spaced at extending distances, both up and down the prevailing wind direction, a similar number being made use of at right angles. The subsequent deposits collected in the rainfall must be carefully analyzed, both as to quantity, weight and structure. The latter determination is done microscopically. The results are then compared with the dusts extracted by the use of the filter probes at one of several suspected sites. In this way the source of emission can be determined. Naturally, of course, should there unfortunately be several sources of emission giving dusts of very similar characteristics then the problem remains indeterminate. For immediate nuisances which may occur in more confined and sheltered areas, the dry petri dish method may be employed.

The petri dish is a round glass vessel of about 3½ inches in diameter, having vertical sides of ½ inch high. The dishes are covered with loosely fitting lids, normally 3⅞ inches in diameter and ⅜ inches deep. Both dish and lid are used for the purpose. From a dozen to two dozen dishes may be used in an investigation, being sited at extending distances up to, say, quarter-of-a-mile intervals over the district to be covered, the larger number being placed in the known or anticipated wind drift. They must be placed above ground, anything from 6 to 10 feet where mechanical interference can be avoided. Also local interference by surrounding buildings or trees must be avoided where possible and the distances from the nearest object should be at least twice the height of the object above the level of the dish. The lids of the respective dishes are placed alongside of them and at the conclusion of 24 or 48 hour periods the dishes are carefully inverted over the lids and are transmitted to the laboratory in that position. Various weather conditions during the tests must be carefully noted and if sudden squalls of rain or wind should develop then the dishes must be immediately collected and replaced when the conditions are again normal. The deposits are carefully weighed and examined as above and the results are expressed again either in tons per square mile per month or as grams per 100 square metres per month. In an area or position where the deposit is heaviest, the source of emission can in this way be located in most instances. The petri dish is useful for sampling various types of ash and process dust which fall rapidly. They are not used to determine the rate or weight of pollutants deposited.

I have endeavoured in this brief survey on methods of practical control to introduce the subject in a way that would be informative and readily understood by those who have not heretofore had experience in dealing with the administrative control of such aerial pollutants. I can only hope that in this effort I may have succeeded.

(3) HEIGHT OF CHIMNEYS

by

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1. In October 1956 Mr. Sandys the then Minister of Housing and Local Government said—"The only sure protection against the ill effects of smog is prevention of air pollution. This . . . will require a sustained effort . . . over a number of years."

The powers of the Clean Air Act relating to height of chimneys have now been in force since 1st January, 1957. The control given to Local Authorities is intended to prevent any additional source of low-level emission of gases.

My purpose is to call attention to the powers and duties of local authorities because it appears that all that can be done is not being done to make such powers effective.

The task of designing chimneys tall enough to secure reasonable dispersal of gases is one for combustion engineers and architects, but both are concerned principally to obtain the efficient use of the fuel employed, and not necessarily to protect public health. Architects generally are horrified to see a chimney sticking out like a sore thumb and make every effort to hide such an ugly erection. This objection has produced a number of monstrosities in an attempt to camouflage the chimney.

Whilst many smoke inspectors are aware of the draught formula given on page 80 of *Efficient Use of Fuels* (H.M.S.O. 1944) much less is known of the work of Sutton, Bosanquet, Hawkins and Nonhebel, about chimneys, in relation to the dispersal of smoke and dust.

For this reason I have attempted in this paper to present a summary of the findings of these investigators to assist local authority officers.

I have benefited from the research of such investigators and am happy to acknowledge its value in my own field.

I also wish to express my thanks to colleagues in the cities and boroughs who have supplied me with information about present practice.

2. Administrative Procedure

Legislation concerning the height of new chimneys is found in Section 10 of the Clean Air Act 1956, which enacts as follows:

> 1. Where plans for the erection or extension of a building outside the administrative County of London other than a building used or to be used wholly for one or more of the following purposes, that is to say as a residence or residences, a shop or shops, or an office or offices, are in accordance with building bye-laws deposited with the local authority and the plans show that it is proposed to construct a chimney for carrying smoke, grit, dust or gases from the building, the local authority shall reject the plans unless they are satisfied that the height of the chimney as shown on the plans will be sufficient to prevent, so far as practicable, the smoke, grit, dust or gases from becoming prejudicial to health or a nuisance having regard to—
> (*a*) the purpose of the chimney;
> (*b*) the position and description of buildings near thereto;
> (*c*) the levels of the neighbouring ground; and
> (*d*) any other matters requiring consideration in the circumstances;

Provision is made for appeal to the Minister if plans are rejected by virtue of this Section.

It will be noted that residences, shops and offices are specifically excluded from the operations of this Section notwithstanding blocks of flats, offices and departmental stores may be heated by boiler plant of considerable capacity.

Some local authorities have the advantage of a local Act which makes good the omission from the Clean Air Act and gives wider control.

The Common form clause generally used in such local Acts sets out the same four points to be considered but provides for its application to " buildings used for manufacturing or *other purposes*."

The powers do not apply to the administrative County of London or to the erection or extension of a generating station as defined in the Electricity (Supply) Act 1919 other than a private generating station.

There is an arrangement in many local authorities for all plans submitted for approval to be passed to the Public Health Inspector for his observations. Under such an arrangemen the officer responsible for air pollution control has an opportunity of expressing an opinion regarding the height of any chimney which may be planned.

The criteria taken into consideration when assessing plans will be broadly those listed in Section 10, but these do not appear to be sufficient on their own.

A certain knowledge of aerodynamics is necessary before deciding what effect the height of adjacent buildings and the levels of neighbouring ground may have on flue gases.

The behaviour of a smoke plume or flue gases is of importance in forming an opinion as to whether they are likely to become a nuisance.

Whilst it is not expected that all who have to consider plans will have a detailed knowledge of the physical phenomena connected with the discharge and dispersal of flue gas, a general knowledge of the main principles involved would appear to be necessary to enable a properly considered opinion to be expressed.

For this reason a resumé of the technical data available has been included in this paper.

3. Technical Data

A great deal of theoretical and experimental work has been done by various workers on the subject of chimneys and the dispersal of smoke and hot waste gases. This has given rise to numbers of formulae applicable to differing sets of physical and atmospheric conditions which will be of use to design engineers and those concerned with the dispersal of atmospheric pollutants.

(i) *Down Draught*

In a paper published in 1955 Hawkins and Nonhebel[1] set out information concerning the effects of disturbance of the air by the passage of wind past the chimney and over adjacent buildings or hills. One effect is down draught which occurs in a region rising to twice the height of the building causing it and extending about six times the height downwind of the building. In this region smoke will be brought down to ground level.

(ii) *Down-wash*

Another effect is down-wash which occurs in the wake formed by a chimney in a wind. It has been found[2] that the wake comprises vertical edies which drift downward drawing smoke with them down to the down-draught region. An investigation[3] showed that down-wash will not occur if the ratio of exit velocity of the gas to the wind velocity is sufficiently high.

A paper by Sherlock and Stalker[2] includes a graph showing for a given wind speed the minimum velocity of flue gas emission for avoiding down-wash.

A paper published by Sherlock and Lesher[3] shows that the height of the flue gases above the ground may be increased by increasing either the chimney height or the velocity of emission.

The external shape of the chimney may have some effect on down-wash and the report of the Committee on Air Pollution says that further research on the design of chimney mouths is required.

(iii) *Smoke Diffusion*

Sutton[4] and Bosanquet[5] have evolved equations to show the maximum concentration at ground level of cold gas emitted from a tall stack. The former is quoted in the report of the Committee on Air Pollution which gives the distance from the chimney at which the maximum concentration occurs as 10 to 15 times the height of the chimney under average meteorological conditions.

The Committee Report[8] states that at whatever height smoke is discharged gravity will eventually bring the larger particles of dust and soot to the ground. Moreover because of the natural turbulence and mixing of the atmosphere, a portion of the finer particles and gases in the smoke will reach the ground although their motion is unaffected by gravity. The higher the point of discharge the greater will be the dilution of the gases and dust by the time they reach the ground.

Sutton's formula[4] for the maximum concentration of cold gas can be written:

$$Y\ \text{max} = \frac{3{\cdot}76 \times 10^6 W}{uh^2}\ \text{mg/m}^3$$

where Y max = the maximum concentration in mg/m^3 at ground level of the constituent in the source

W = strength of source (lbs/sec) e.g. of SO_2, fine dust or total flue gas

U = wind speed (ft/sec)

h = height of stack (ft)

mg/m^3 = milligrams per cubic metre (for SO_2, $1\text{mg/m}^3 = 0{\cdot}35$ p.p.m.)

In the same report an American Formula is quoted by computing the maximum ground level concentration of gas from a hot source. In this case the distance from the chimney at which the maximum concentration occurs is given as 25 to 35 times the height of the chimney.

This formula is written as

$$C = \frac{9 \times 10^6 W}{h\ (14\ vd + Q)}\ \text{mg/m}^3$$

W = Weight in pounds per second of flue gas or dust;

h = Height of stack;

v = Velocity of flue gas in feet per second;

d = Diameter of stack (ft.);

Q = Rate of heat output relative to air temperature; (B.Th.U. per second)

(iv) *Effect of Temperature on Height of Emission*

It has been shown[6], that 1-lb. of flue gas at 150°C. will have in air at 10°C. a of buoyancy about ½-lb. weight which would give a theoretical upward acceleration of 14′ per second. In addition the gases possess an upward velocity which will carry them above the chimney top. One observer[6] has estimated in connection with one plant that an increase of 1°F. in the effluent gas temperature is equivalent to adding 2½ ft. to the chimney height.

When the gases cease to rise due to

their loss of buoyancy or initial velocity they behave in the same way as a similar quantity of cool gas.

Concerning the height of rise of a smoke plume above the chimney top Hawkins and Nonhebel have set out the following conclusions which they state are supported both by theory and observation.

1. The higher the temperature of the gas, the higher it will rise (as an extreme case, the plume from an atom bomb explosion rises 10 to 20 miles, and the agreement between the estimated rise with the observed rise is good).
2. The larger the quantity of gas emitted per unit of time, the higher it will rise.
3. As the wind speed increases across the chimney the height of rise is reduced.
4. The height of rise is greater in conditions of large lapse (i.e. air temperature decreasing rapidly with height), than in conditions of light lapse or inversion, (i.e. air temperature decreasing slowly with height or increasing with height).

(v) *Height of Rise of Hot Gases*

Bosanquet has evolved a formula for calculating the rise of hot gases above a chimney. Examples of the application of this formula and comparisons of the observed and calculated rise are given in the paper by Hawkins and Nonhebel.

(vi) *Pollution from Adjacent Chimneys*

Hawkins and Nonhebel[1] state that the gas concentration caused by several chimneys at any one point is simply the sum of the concentrations caused by each chimney considered separately. There is therefore no advantage in discharging the flue gas from a large factory or power station through several chimneys. In fact a single chimney taking the same volume of flue gas would, by increase in velocity of discharge, have a greater effective height and therefore produce smaller ground level concentrations.

(vii) *Dust Deposit*

Hawkins and Nonhebel[1] state that for dust particles having a diameter of less than 20μ the free falling speed is so low in comparison with the wind speed that the particles diffuse with the gas stream.

As the size of the particles increase they reach the ground before the gases and the particles below 20μ in diameter. Bosanquet has shown that the point of maximum deposit of particles above 20μ in diameter is at a distance of 8 to 10 times the height of emission. If particles greater than 150μ in diameter are removed from the flue gas the point of maximum deposition has been shown by Bosanquet, Carey and Halton[7], to be 9 times the emission height from the chimney.

4. Combustion Requirements

In power stations and large industrial plants the function of a chimney is to secure adequate and satisfactory dispersal of the flue gases. The draught necessary for combustion can more easily and cheaply be provided by fans.

In smaller plants however, the chimney still plays its part as a creator of draught and unless it is adequate in design and size for this purpose, poor combustion and smoke emission will result.

Inefficient combustion is frequently due to the draught being inadequate to burn the amount of fuel fed on to the grate or failure to make use of the draught available. Natural draught is governed by:

(*a*) the height of the chimney, and

(*b*) the average temperature of the gases in the chimney. The higher the chimney and the hotter the gases the greater the draught.

The height of a chimney needed to produce a required draught may be calculated from the formula:

$$H = \frac{D}{\left(\frac{7 \cdot 6}{t_1 + 460} = \frac{7 \cdot 9}{t_2 + 460}\right)}$$

H=height of chimney in feet
D=draught in inches water gauge
t_1=outer air temperature in °F. (assumed to be 60)
t_2=mean temperature in the chimney in °F.
7·6 & 7·9=weight in lbs. of 100 cu. ft. of air and flue gas at 60°F.

For a given chimney height and a known mean temperature this formula can also be used to work out the draught that should be available.

The mean temperature in the chimney can be deduced by subtracting 1°F. from the recorded chimney base temperature for every 3 ft. of height.

The draught required depends on the nature of the fuel, the depth of fire, the rate of combustion desired and any resistance in the flues and ancillaries to the boiler.

Some coals require more draught than others. Coke, anthracite and low volatile coals require a strong draught since nearly all the air required for the combustion of these fuels must be drawn through the firebed.

With higher volatile fuels the volatiles are burned with secondary air drawn through openings which offer little resistance to flow. The draught therefore necessary to provide secondary air is considerably less than that needed for primary air.

5. Overseas Practice

(1) *U.S.A.*

Communications were sent by the Association of Public Health Inspectors to three Cities in U.S.A. regarding the construction of chimneys.

In their replies all three set out particulars of the controls which are exercised over the height of chimneys but none has evolved a clear cut system of calculating the height of a chimney necessary to prevent nuisance.

The City of Cincinnati has certain technical requirements concerning the height of the chimney as it effects the combustion efficiency.

The City of New York is about to issue standards of chimney sizes and heights but at present seems to rely on the furnace manufacturers recommendations.

The City of Columbus, Ohio, has more precise regulations. Amongst other requirements is one which states that all chimneys shall extend a minimum of 5 ft. above any wall, coping, saw-tooth roof, penthouse, or other obstacle on buildings where fuel-burning equipment is installed. Chimneys are required to be high enough to allow sufficient clearance above adjacent buildings and to allow dispersal of chimney emissions without causing a nuisance.

The Chief Smoke Regulation Engineer of the City of Columbus states, " We are still looking for reliable criteria to use in appropriate chimney heights. Many papers have been written in recent years on wind tunnel tests, etc., but I have yet to find a practical method of using such information in our day to day chimney problems."

(2) *U.S.S.R.*

The control of atmospheric pollution in Russia includes regulations to secure dispersal and avoidance of high concentrations in the vicinity of residential areas.

This is achieved by zoning into residential and industrial areas and establishing an adequately wide restricted area between them whereby the industrial district should be located on the leeside of the residential district.

Regulations are in force specifying zones according to the nature of the industry and all industries are divided into five categories according to the nature of the emissions from them. The most harmful are separated from residential buildings by a zone of 1,000 metres and the least harmful 50 metres.

Where no ash collecting installations are available or the cleaning efficiency is less than 50 per cent., the zone of separation may be expanded, but not more than twice.

Boiler plant for heating purposes in the vicinity of houses burning 5 tons of coal an hour or more are separated from the houses by a zone of vegetation at least 50 metres wide. The height of chimneys of such plants must be 10 metres higher than the tallest building within a radius of 100 metres.

6. Practical Application

(i) *Sulphur Dioxide Concentration*

The main purpose of controlling heights of chimneys is to keep the ground level concentration of gases, smoke and dust below the point where they cause nuisance or present a hazard to health. This involves the fixing of upper limits particularly in the case of sulphur dioxide concentrations.

No official guidance has yet been given as to what the maximum allowable concentration of sulphur dioxide should be. The Department of Scientific and Industrial Research booklet " Sulphur Dioxide " in the series " Method of detection of toxic gases in industry " gives the maximum allowable concentration of SO_2 for several hours exposure as ·03 mg/litre or 30 mg/m^3.

Ronald Williams and D. C. Norcliffe say that the maximum allowable concentration of various contaminants established for industry do not always apply to problems of community air pollution. The public is exposed continuously and not as with industrial workers for limited periods (usually eight hours).

They quote an American source " which suggests that the maximum allowance concentration for 24 hour periods should be as low as 1/10th of the concentrations acceptable for an eight hour exposure, thus compensating for loss of recuperation possible during the 16 hours an industrial employee is away from work."

In Leeds a standard has been fixed at 0·4 p.p.m. (for SO_2 1/mg/m^3 = 0·35 p.p.m.) of SO_2 as a maximum allowable concentration. Sutton's formula already quoted in this paper is used for estimating the maximum ground level concentration which will arise from a source of emission. For the purpose of the Sutton formula an average wind speed of 9 ft. per second (5 m.p.h.) has been accepted. It is said that this calculation gives reasonable chimney heights.

Normal London atmosphere has 0·2 mg/m^3 of SO_2 but during the " smog " of December 1952 when 4,000 people died, the concentration rose to over 4 mg/m^3. It is possible of course that the toxic effect of low concentrations may be increased by other pollutants in the atmosphere.

With the increase in the number of oil fired installations, particularly packaged boilers, which have comparatively low chimneys with no obvious smoke emission, it may be that as Williams and Norcliffe[10] suggest, regional surveys should be undertaken to relate background levels of SO_2 to possible additions in the concentration due to future development.

(ii) *Smoke Emission*

One important point to be resolved is the efficacy of the various formulae when considering what height of chimney is necessary in each specific case.

Are we to accept the formulae given in the Report of the Committee on Air Pollution[8] and other formulae available, or are they too rigid and extravagant? Are the hypotheses upon which they are based reasonable and likely to be encountered in practice?

Is the suggestion in the Report[8] that " pending further research on the subject, a good working rule for low buildings is to make the chimney not less than 120 ft. high " acceptable.

J. H. Wyatt of Leeds considers unsatisfactory the formulae for calculating the maximum ground level concentration of hot gases[9]. He writes " in the absence of a suitable formulae, after consultation with engineers in private practice and in Corporation employ, a series of minimum heights normally acceptable as reasonable have been evolved. These heights are purely empirical and assume that the buildings concerned are single-storeyed and built on level sites. We suggest that (1) for small central heating plants burning smokeless fuel, the minimum height should be 30 ft. from ground level; (2) for small plants burning bituminous coal with underfeed stokers the minimum height should be 45 ft.; and (3) for small coal-fired steam-raising plants using other types of stokers the height should be at least 60 ft. For larger installations, say one or more Lancashire boilers, the height should not be less than 120 ft. as is suggested in the Beaver Report. . . . It should be emphasized that these are regarded as minimum heights. At present the question is being considered whether or not they should be increased to a 40 ft. minimum."

In connection with these minimum heights consideration has to be given to the temperature and velocity of discharge of the flue gases. These factors depend on the type and efficiency of the installation.

(iii) *Present Practice*

Enquiries were made of a number of Local Authorities on the operation of Section 10 of the Clean Air Act and a resumé of replies received follows.

The City of Leeds appear to have had much more experience in this matter of chimney heights than other Local Authorities. As will be seen from the table no less than 119 plans have been examined for the purpose. This figure includes a proportion of plans which could not have been dealt with under Section 10 of the Clean Air Act but which come within the scope of a private Act, the terms of reference of which are really the same as Section 10 but which extend powers to include all types of buildings.

It may well be that a conflict of interests will arise between designers who are anxious to preserve the external appearance of their buildings and the officers of the Local Authority who may be anxious to raise the point of discharge of flue gases. There will be many cases in which a compromise has to be agreed upon to strike a balance between preserving the amenities of the district and preventing pollution of the atmosphere in the neighbourhood.

I wish to acknowledge the assistance I have received in the preparation of this paper from Mr. E. A. Ellis, Smoke Inspector, Barking.

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REPLIES FROM LOCAL AUTHORITIES

Name of Local Authority 1	*Officer of L.A. who examined plans* 2	*Number examined since 1.1.57* 3	*Number of appeals to Minister* 4	*Criteria taken into consideration when assessing plans* 5
Birmingham	Chief Smoke Inspector	37	Nil	Practical considerations and local circumstances. Boiler rating. Type of fuel and consumption. Methods of draught.
Bolton	Borough Engineer and Surveyor	19	Nil	The matters referred to in the Section and what can be said to be reasonably practicable having regard to all the circumstances of the particular case.
Coventry	Chief Public Health Inspector	26	Nil	Type of plant. Method of stoking, grit arrestment. Type of fuel and burning rate. Maximum SO_2 concentration compared with the allowable concentration.
Doncaster	Borough Surveyor	—	—	No information given.
Kingston upon Hull	City Architect with Chief Public Health Inspector and Smoke Inspector	14	Nil	Type of boiler. Capacity of boiler. Type of fuel. Method of firing. Proximity and height of surrounding buildings.
Leeds	Chief Public Health Inspector or Deputy	119	Nil	Section 10 Clean Air Act, 1956. Minimum heights fixed. Maximum allowable concentration of SO_2 fixed at 0·4 p.p.m. Sutton's Formula used.
(The plans referred to in Col. 3 are made up as follows:—)				
	Factories	73		
	Offices, stores, shops	18		
	Schools	17		
	Hotels	6		
	Churches	5		
Liverpool	Chief Public Health Inspector	34	Nil	Purpose of chimney. Method of firing. Height of adjoining buildings and levels of neighbouring ground.

Name of Local Authority 1	*Officer of L.A. who examined plans* 2	*Number examined since 1.1.57* 3	*Number of appeals to Minister* 4	*Criteria taken into consideration when assessing plans* 5
Manchester	Public Health Inspectors specializing in Smoke Prevention	24	Nil	Appendix VI—Report of Committee on Air Pollution Topographical conditions. Height and proximity of adjacent buildings.
Newcastle upon Tyne	Chief Engineer and Surveyor	30	Nil	Section 10 Clean Air Act, 1956. Site examination. Prevailing winds. Filtration methods adopted.
Preston	Smoke Inspector	3	Nil	Efficient combustion.
Sheffield and District Clean Air Committee	Chief Smoke Inspector	3/4 a month	Nil	Section 10 Clean Air Act, 1956. Amount of fuel burned. The higher the chimney the better.
Smethwick	Chief Public Health Inspector	6	Nil	Clean Air Act. Memorandum of miscellaneous provisions paragraphs 15 and 16.
Walsall	Chief Public Health Inspector and Borough Surveyor	3	Nil	Type of process. Nature and amount of fuel burned. Method of firing. Topography of the district.
West Bromwich	Chief Public Health Inspector	1	Nil	Appendix VI—Beaver Report Memorandum on Miscellaneous Provisions. Clean Air Act Efficient Use of Fuel. H.M.S.O. 1944, page 80.

Discussion

G. Nonhebel (Individual Member) in opening the discussion, said that the authors had given excellent reviews of the problems. As regards smoke emissions, it would appear from observations made on numerous long train journeys by himself and his technical friends, that there had been a marked diminution in the amount of dark smoke issuing from industrial chimneys in the Black Areas. He was glad to hear that Mr. Farquharson confirmed that many cases of excessive smoke emission could be stopped by better factory management without any expenditure on equipment. Nevertheless, as had been said at the Brighton Conference as long ago as 1946, provision of smoke density recorders did help the plant operators, especially if an interest in the readings was taken by the management and the men suitably encouraged.

He was pleased to see that Mr. Farquharson's own measurements of smoke produced during sootblowing were in agreement with those published in British Standard 2978:1958—Measurement of Smoke Emission from Medium Capacity Coal Fired Water-tube Boilers with Chaingrates. The British Standards Committee were now engaged in making measurements of the smoke emission from well run Lancashire and Economic boilers. He believed that difficulties with smoke from plants using caking coals, where slicing of the fires had to be frequent, could be overcome by use of much shorter slicing tools giving minimum disturbance of the coal bed at the back end of the grate.

Mr. Bastable had given a clear account of the problem of approving the height of a new chimney. One of the most interesting points in the paper was the statement that Leeds had decided that the calculated maximum ground level concentration arising from a large new industrial chimney should not exceed 0·4 parts per million of SO_2. He hoped that Mr. Goodfellow of Leeds would tell the Conference the reasons for choosing this particular limiting concentration. He was not in agreement with use by Leeds of the Sutton formula without taking into account the thermal rise of the gas by the method of calculation given by Bosanquet, *J. Inst. of Fuel*, Vol. 30, p.332, 1957.

With regard to smaller plants, Mr. Nonhebel had recently come across a case of a large central heating plant of several Lancashire boilers where sulphur fumes had become a real nuisance in some offices when a change had been made to oil firing: the reason was that the chimney did not protrude sufficiently high above the ridge of the roof and the higher SO_2 arising from the change of fuel and the higher CO_2 (and hence less diluted flue gas) had raised the sulphur concentration outside the offices above the threshold value of tolerance.

Mr. Ashworth had mentioned difficulties in identification of dust: much assistance could now be obtained by comparing the dust samples under the microscope with the colour photos given in the ' Air Pollution,' edited by M.W. Thring, the printed version of lectures at Sheffield University.

J. Goodfellow (C.P.H.I., Leeds) replied to Mr. Nonhebel on why Leeds had fixed a maximum permissible ground level concentration of sulphur dioxide of 0·3 p.p.m. He said that he did not agree with Mr. Bastable that there should be a national standard, and did not think it practicable nor desirable to fix a standard national allowable concentration of sulphur dioxide. Nevertheless he thought that Leeds was perfectly justified in fixing 0·3 p.p.m. as the maximum allowable ground level concentration from any new source in the City.

He said that if you asked him " What should be the maximum allowable concentration from a new plant to be located on the Great Orme? " he would say in all sincerity " the sky is the limit." The point he was making was, that each local authority that wished to determine what maximum ground concentration of sulphur dioxide it should permit should take into consideration (i) its own existing pollution level and (ii) the local topographic, geographic, and climatic factors.

In the case of the City of Leeds—to start with Leeds was already a smoky city; it already had a fairly steady level of sulphur dioxide. Then he believed some towns in exposed places had an average wind speed of up to 30 ft. per second. Some had an average wind speed of 15 ft. per second. Leeds was in the Aire Valley and was very sheltered. It had an average wind speed of 9 ft. per second.

Then as regards topography, Leeds in the Aire Valley had hills approximately 400 ft. high to the north-west, to the west and to the south. The result was that after a cold wind had been blowing from the north-east if there was a change of climatic conditions, and a warm wind blew from the south, south-west or west, this warm air coming over the hills rode right over the existing cold ground air already in possession of Leeds, and thus they got conditions of temperature inversion very frequently.

He therefore maintained that in all these special circumstances, the Leeds Health Department was fully justified in having fixed the maximum allowable concentration of sulphur dioxide at 0·3 p.p.m.

Councillor W. A. Norman Jones (Birmingham) said that the financial repercussions of the Clean Air Act should be faced squarely, by elected representatives. The benefits to be gained from cleaning the air would pay for the initial capital outlays.

Large numbers of hand-fired boilers would be a source of trouble for some time; unless more definite steps were taken to convert to automatic firing as a first essential at earliest date practicable. Meantime operatives should be given every encouragement and even monetary rewards to become proficient boilermen.

Soot-blowing was in his opinion one of the worst ways of polluting the air, and in allowing longer time for dark smoke emissions during soot-blowing the Act was weak. Surely the proper way was to *draw* soot out of the furnace, not blow it into the air.

As regards their old faithful but now supposedly redundant steam locomotive, and its pollution nuisances—these could be greatly lessened, at the engine shed particularly, by the use of Coalite for lighting-up purposes. The supply of the better grades of coal for the heavy and speedy types of train, with careful firing, would certainly make for less pollution from this source.

Arthur Coe (College of Fuel Technology) referring to the technique described to pin point a grit and dust nuisance from one of a number of chimneys, suggested that this could be tackled more simply and reliably by using the survey powers of the grit and dust Sections of the Act.

Excessive grit and dust emission could arise solely from the use of unsuitable fuel, or from overloading, which with common sense could be avoided, or from faulty draught arrangements, or from bad operation, or a combination of these factors, the correction of which would pay and pay handsomely. This meant using the survey powers under the Act to tackle the group of works concerned, with maybe in the end substantially reducing grit and dust emission from most of them.

The principle difficulty however with the removal of grit and dust was the cost. Measures which resulted in fuel saving paid for themselves, but grit and dust removal could be a dead loss—could be because contraventions which arose with respect to grit and dust emission from faults in operation, meant also heavier fuel costs which it would pay to correct. It was when changes which yielded a return were not fully effective, that the question arose of the installation of a grit and dust arrestor which would impose an additional unremunerative charge on the undertaking, unless it was that in installing such equipment a lower grade of coal could be used, without offence, at a difference in price which would meet the capital, running and maintenance charges on this equipment.

The National Coal Board had large quantities of low grade coal to dispose of, and industry would have sooner or later to burn it without contravening the Act. It would therefore seem that a necessary step towards this was " a price differential " between high and low grade coals sufficient to justify the installation of grit and dust arrestors. Thus putting the installation of grit and dust arrestors on a sound economic basis—that was, on the same basis as the installation of fuel efficiency plant.

Councillor W. A. Beardsley (Southwell R.D.C.) said his Council would like the answer to several problems. He felt the Ministry should be responsible for taking action in the Courts, particularly in the early stages of the application of the Clean Air Act. He quoted the case of the Nottingham Borough Council and the Nottingham General Hospital, where the Regional Hospital Board claimed it was Crown property. The case was lost and the litigation costs must have been quite high. He also asked whether the Town and Country Planning Committees got technical advice before laying down planning conditions. In his own area, certain planning conditions were laid down for a coking plant. It was then found out afterwards that the owners said they could not have met some of these conditions. They were now asking for permission to erect the second stage of this plant. What was the answer to this problem? He hoped the Conference could tell him.

The last point he wanted the Conference to consider was amendment of the Act, to limit the amount of sulphur dioxide that could be discharged in the air. The readings of percentage discharge of sulphur dioxide should be taken when the highest concentrations were being given off; and not aggregate readings over longer periods.

P. Draper, M.I.Mech.E., F.Inst.Pet. (Shell-Mex and B.P. Ltd.) said that having been asked many times what the height of a chimney should be for an oil-fired installation and having searched through the literature for clues felt that he could readily congratulate Mr. Bastable on having gathered together so much of the relevant information and thanked him for making it available for others to use.

He thought, however, that those who have hoped for a scientific or rule of thumb means of determining chimney height would be disappointed because it was quite clear that in the end the best compromise for chimney height would be a matter for common sense or intelligent guess.

Of the many factors mentioned in the lecture he thought that one of the first considerations, that of down draught due to currents of air being deflected over buildings, might be described in more detail. He showed a diagram, Fig. 1, indicating two similar buildings of flat roof design subjected to currents of wind indicating how the air was deflected up and over the buildings causing a low pressure zone on the roof and in the lee of the buildings, which meant that some air must move downwards. In the first case a very short chimney was provided which could only introduce the product of combustion into a down current of air and he suggested that this design was all too frequently encountered at the present time. The chimney on the other building was extended to a height between one-and-a-half times and twice that of the building and was indicated as carrying the products of combustion through the down draught zone so that they would be properly dispersed. Whether such a chimney should be twice the height of a building as suggested by the reference to Hawkins and Nonhebel or whether one-and-a-half times would do must be guessed and then proved by practical experience.

He thought Mr. Bastable quite right in stating that many modern combustion appliances did not need a high stack for combustion draught purposes nor for carrying away the smoke which might be invisible, but he considered it an equally important function of a chimney to ensure that the products of combustion should be emitted where they have a reasonable chance of being properly dispersed.

Mr. Draper felt also that a word of warning was necessary about the hot and cold flue gas formulae in the Beaver Report. He thought these formulae were often seized upon as being tangible means for calculating either chimney height or concentrations of pollutants at ground level, but since it is not really known what are acceptable concentrations of pollutants he thought the calculations were generally of little value.

On the difficult subject of limits of acceptable pollution he thought Mr. Bastable's figures were useful, but that they must be compared in common units. Mr. Bastable quoted the D.S.I.R. as proposing a maximum allowable concentration of sulphur dioxide for several hours of exposure of 0·03 milligrams per litre, which is equal to ten parts per million. At this stage he produced another diagram, Fig. 2, comparing with this ten parts per million the limit decided upon by the Leeds Authorities and the average concentrations in London under normal conditions and during the bad smog of 1952. Two other much heavier concentrations were shown for the least causing coughing and the maximum for short exposure respectively. He also quoted a report from America that SO_2 concentrations up to 0·2 p.p.m. reduced the damage to plant life caused by ozone in the Los Angeles area, thus he thought that taken by themselves the concentrations of sulphur oxides as gases normally present in the atmosphere made one wonder if they were of any significance at all.

He stated, however, that there might be a catch in this to make the position more difficult. For instance if one imagined a normal harmless concentration of sulphur oxide gas in a cubic foot of air and then supposed that all this sulphur oxide could be concentrated on to a nucleus such as a particle of carbon, then the cubic foot of air would still be harmless but the speck of carbon loaded with sulphur oxide could settle on a moist

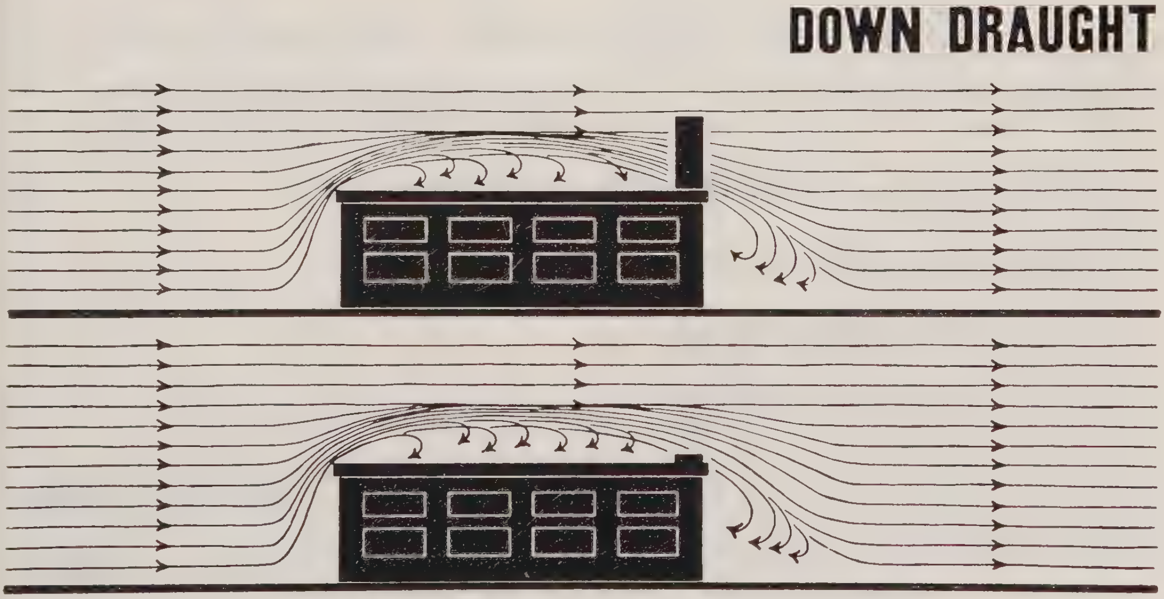

Fig. 1

surface and become acidic and a minute spot of damage could occur. If this were multiplied many thousands of times a more widespread damage could be understood, even though the original concentration of sulphur oxide in the air was quite harmless. It was for this reason that the reduction of smoke, smut and grit played such an important part not only in reducing the dirt damage but also in reducing the corrosive damage. He hoped that this glimpse of the perspective would help to clear the air on the subject.

Councillor C. A. Watson (Scunthorpe Borough Council) said that the problem of clean air resolved itself into two main aspects, the proper combustion of fuels and the pollution caused by industrial processes. In regard to the first, the remedy was both available and practicable. It needed but the proper use of efficient appliances, trained staffing and the use of suitable fuels. This applied both to industrial and domestic users of heating appliances.

In regard to pollutions which were the result of industrial processes, a much more difficult and complicated problem, it was impossible that the provisions of the Act could make any real improvement in the foreseeable future. The task given to Alkali Inspectors was an impossible one in that only 20 would be available to cover the whole country. What would the financial condition of the nation be if there were only 20 tax inspectors and what fun and profit it would be to make frequent trips to the continent for even the Channel Islands if the Customs and Excise Service had only 20 port inspectors.

What was needed was a new approach to be made. In this day and age, industry was organised into associations with mutual interests and problems and it was urged that these associations be approached either by the Government or by this Society, to study and report on pollution caused by processes used in the industry.

In this connection he wished to quote the example of the Iron and Steel Industry. In September 1957, the Iron and Steel Institute held a conference of their members to which were invited, amongst others, members and officers of some local authorities, in whose areas the steel works were situated. Papers were read by experts indicating some of the problems of pollution and the extent to which efforts were being made to apply known remedies or palliatives and of difficulties which made the application of existing knowledge impracticable. Further, the industry was doing work in its research department to explore existing and future pollution problems.

Mention had been made already of what had successfully been done by one section of the industry, and the view was expressed that in present circumstances, far better results could be more quickly achieved with that kind of co-operation than could be expected from any procedure laid down in the Act.

Informal talks at the Conference and elsewhere lead to a conviction that except in connurbations, pollution which was the

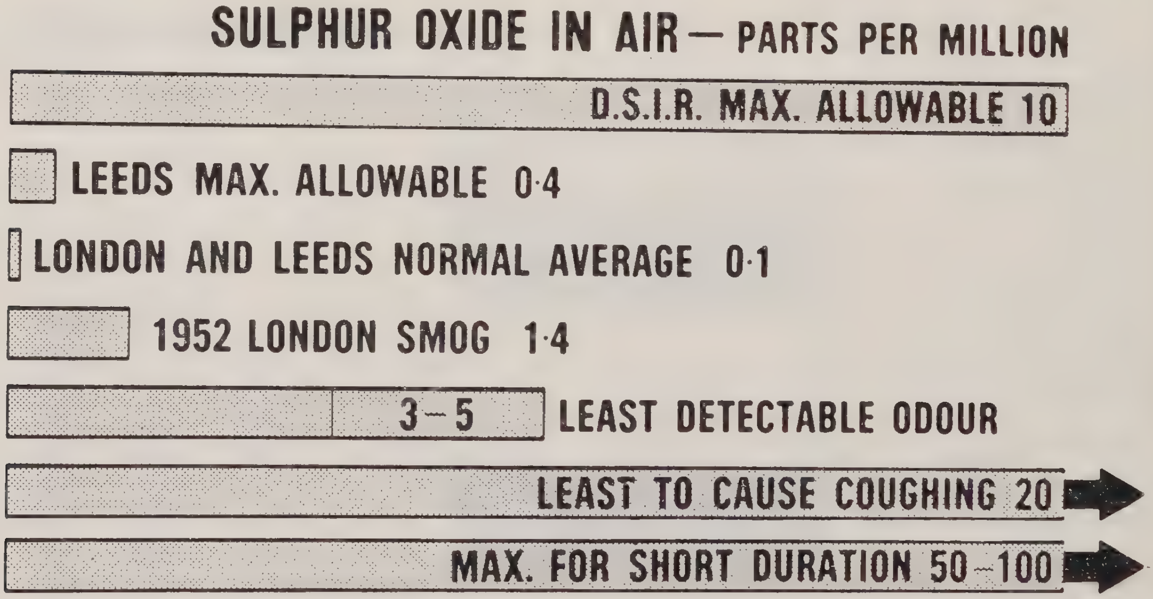

Fig. 2

result of industrial processes, was a greater menace to health and amenity, was a far more difficult and complicated problem and needed more urgent and constant attention than that of smoke caused by industrial or domestic fuel users. It was one which would be with us always, as new processes and methods of production were evolved. The Society was therefore urged to ask the Government to encourage such surveys and publish results, through industry or themselves, to make such approaches.

W. H. Wattleworth (C.P.H.I., Liverpool) questioned the large number of exemptions which would appear to be building up under the Clean Air Act. He pointed out that some premises were directly exempted and some indirectly by reason of their size or technical difficulties. These exemptions included Crown properties and certain nationalized industries.

Temporary exemptions destroyed the intention of the Beaver Report to promote reduced pollution quickly and efficiently. Furthermore, it was now being considered that exemption should be given to mechanical stokers, yet it was known that certain mechanical stokers required constant attention by expert technical supervision and continuous delivery of the right kind of fuel. It had been found that these particular stokers had been under the supervision of non-technical people and consequently considerable nuisance had been caused.

With regard to the question of the Dark Smoke (Permitted Periods) (Vessels) Regulations, 1958, he was of the opinion that Port Health authorities had been let down in their hopes to remove smoke from our rivers and ports.

In the case of buildings, a suitably trained inspector could decide whether any of the defences of Section 2 of the Act would apply, but an observer stationed ashore would have no idea of the cause of smoke and until a case was presented at Court no information need be given as to whether any defences are to be used.

The Regulations did not permit the emission of black smoke for more than three minutes in any period of 30 minutes, or dark smoke for more than 20 minutes in any one hour. Considering that vessels travel at some 11 knots, a vessel under observation might pass through the length of jurisdiction, or be out of sight before the observation was complete. In other words, almost total exemption had been given to all vessels whilst under way!

Dr. R. Jackson (British Coal Utilization Research Association) said that the three papers showed some of the difficulties in implementing the Act. Mr. Farquharson had dealt with emission of dark smoke. Dark smoke was defined by the Act, the method of measurement was laid down and excessive emission had been specified. As a result Mr. Farquharson had been able to concentrate on the successes that he had had in reducing smoke emission. Both Mr. Ashford and Mr. Bastable had had a more difficult problem as the Act did not specify what constituted excessive pollution—either from grit and dust or from gases, nor did it define the methods of measurement.

In his discussion of the problem of measurement Mr. Ashford had concentrated almost entirely on the use of the deposit gauge; this was neither precise, reproducible, nor reliable and if it were to be used as an indication of the source of a particular emission then it had to be interpreted by an expert and even he might have considerable difficulty in doing that. These forms of measurement were generally only of value in a locality containing only one possible source of pollution as, for example, in a country area containing a single large industrial works. A more direct method was to determine the emission from a single stack. This could give a positive answer to whether that particular stack was causing excessive pollution and the answer was unaffected by emission from other stacks. Although that was the obvious method of tackling the grit and dust problem it had only been mentioned in passing by Mr. Ashford and the measurement technique referred to involved the use of a Whatman filter thimble; this thimble was of value only in a limited number of cases and had been abandoned for general use.

The Conference might be interested to know that B.C.U.R.A. had developed a simple technique for the measurement of grit and dust emission, the equipment was now commercially available and the Association was actively engaged in drawing up a statement giving the details of the method. In general it could be said that the measurement of emission in this way was not so difficult as many persons expected. On the other hand it was not so simple that an inexperienced person could not make mistakes. A British Standard Specification defining this and other methods of measurement was also in course of preparation.

Turning to the practical problem of

dust collection, the overall feature of dust collectors which Mr. Ashford had not stressed was the importance of the size of the particles to be collected. The equipment was simple and the cost was low. The smaller the particles being emitted the more difficult the task of collection became. An increase in the efficiency of any form of collector was often accomplished by an increase in complexity of the plant; it was important to realize when the purchase of gas cleaning plant was considered that the more complicated the equipment, the greater was the need for efficient maintenance. Dr. Jackson had knowledge of an efficient type of collector that, through lack of effective maintenance, had virtually ceased to function and its efficiency was so low that its replacement by a large empty box used as a settling chamber would have been an improvement.

Dr. Jackson was sorry to see that Mr. Ashford had fallen into the common trap of quoting efficiencies without referring to the size of dust. Such figures could be very misleading; a cyclone or even a settling chamber might have efficiencies varying from nothing up to 100 per cent. according to the type of dust involved. There was also a dangerous statement that a multi-stage arrangement of separators gives improved efficiency. If the first collector of the series were operated at maximum efficiency, that is, for example, if it were not overloaded, then the subsequent collectors of similar type would catch little additional material. There was often of course advantages in having a series arrangement of different types of collectors.

Mr. Ashford had quoted an efficiency of 99·9 per cent. Dr. Jackson said that he would be interested in knowing the type of plant and manufacturers of the equipment on which such efficiencies were obtained as values much in excess of 99 per cent. were unusual because the cost of plant to provide these higher efficiencies rose steeply with increase of efficiency. In the description given of the operation of electrostatic precipitators it had been said that the rapping of the electrodes caused the dust to fall into the hopper; while this was true of some of the dust it was also well known that such rapping could liberate dust into the gas stream and often considerable quantities of this dust were carried through to atmosphere. The calculations of possible deposits from chimneys, quoted from a paper by P. E. Aldridge, referred only to fall out according to Stokes' Law. that is under stream line conditions which of course never apply in practice. The more complete story was given in Mr. Bastable's paper. It was for this reason unfortunate that it had been stated that, " based on Stokes' Law, experiments had shown that the fall out . . .". The experiments presumably had been carried out in the laboratory and not from an actual chimney.

Referring to the Paper by Mr. Bastable, Dr. Jackson said that while the arguments used by Mr. Bastable and the figures quoted as to the distribution of different sized particles and gases around a chimney were correct, Mr. Bastable's conclusions were not necessarily valid. He himself would favour a different approach. The emission could be considered to consist of grit and fine particles or gases; the grit tended to fall in the immediate locality whereas the finer material and gases were more widely dispersed. Although raising the height of a chimney would cause a reduction in the concentration of grit per square yard the same total weight of grit would fall to the ground somewhere. It was merely that it was spread over a greater area. On the other hand gases and fine particles might be dispersed not only over a larger area of country but also outside the country itself and be deposited in the sea. In this case raising the height of a chimney effectively reduced the amount of pollution falling upon the land. This could be a useful contribution to clean air, whereas with grit a much better solution, and possibly a cheaper one, was to fit efficient grit arrestors and not necessarily to raise the height of the chimney.

D. G. Tonkin (C.P.H.I., East Ham) said that following Mr. Ashworth's paper he wished to speak on a subject which, though not part of the Clean Air Act, was closely allied to it and might indeed be said to have caused problems as a direct result of the Act.

He referred to the stock piling of coke at gas works and said that delegates must have noticed in their travelling to the Conference that wherever there was a gas works there was also a large pile of coke. In his district they had the biggest gas works in the world, and as a result an enormous pile of coke was deposited there. At this and other works it was quite possible where they were situate near houses that when the wind was in the right direction a serious nuisance could be caused to tenants of houses by dust and grit blowing off the tips.

He appreciated that this was really a matter for Public Health Act legislation where a nuisance was actually proved, but he did not think that housewives would be interested under which particular Act local authorities took action, and in any case there was little difference between the grit that might be blown off the tips, and grit and dust which was emitted from factory chimneys. He suggested that a way of curing the trouble was to reduce the price of coke and carry out a campaign to get the cheap coke into people's houses now.

There was no point in curing one nuisance by starting another, and although he realized that Gas Boards and their officials were taking a keen interest in the Clean Air Act and were doing much to further its cause, he thought they should not wait for the operation of Smoke Control Areas, but endeavour to educate people in the use of smokeless fuels now.

C. H. Crawford (C.P.H.I., Brierley Hill) said he thought Mr. Farquharson was unduly pessimistic in thinking that the impetus of publicity would decline and result in less attention being paid to the Act. More credit should be given to the amount of effort made by industrialists to put their plant in order in time for June 1st.

Local Authorities should never lose sight of the need to keep staff available to watch factories and let owners know that this was being done.

In relation to Mr. Bastable's paper he thought that local weather conditions, particularly high humidities, were of great significance when considering permissible concentrations of SO_2 at ground level.

Councillor John Dilworth (Derby) accused the Minister of Housing and Local Government of frustrating local authorities in their efforts to implement the provisions of the Clean Air Act.

He went on to say that firms who had had pressure brought upon them by the local authority were now making application to the Minister for exemption under the Act, and although the Minister grants the application the local authority knows nothing about it. He also said that they in Derby had asked the Minister before he granted a certificate of exemption to write to the local authority and ask for their observations.

He said it was felt in some quarters that the fact that the Minister was appointing more alkali officers was because many factories were going to " hide behind these inspectors," and that local authorities were being frustrated.

Councillor Dilworth referred to the problem of domestic chimneys and said the present cost of smokeless fuels was too high for the ordinary working man, and unless the price was reduced to the same basis as for the sale of coal, they would not sell smokeless fuels and the Act would not be a success.

H. E. T. Lowbridge (C.P.H.I., Willenhall) noted in Mr. Farquharson's paper, his appreciation of the usefulness of the issue of temporary exemption certificates especially in view of the fact that in a paper given at Blackpool to the Association of Public Health Inspectors it was apparent that some local authorities were reluctant to grant certificates.

He instanced a Company which had the greatest difficulty in complying with the Clean Air Act—that they were doing their best and were taking steps to replace the existing coal-fired boiler plant with electrically driven equipment and that the complete alterations would take 12 months. The firm asked for consideration until the new plant was installed. An application for a Certificate of Temporary Exemption was made and the Council had granted this.

This was an example of the type of co-operation which was desirable. Mr. Lowbridge asked if representatives could give reasons for local authorities refusing to issue Certificates.

With reference to Mr. Ashford's paper, Mr. Lowbridge instanced a particular nuisance existing in his part of the country and the steps which were taken to overcome it—that was the nuisance of grit and dust from foundry cupolas. Cupolas in the United Kingdom emitted some 40,000 tons of grit per year into the atmosphere. In the Midlands and other industrial areas thousands of these cupolas could be seen. A cupola could be simply described as an apparatus for the melting of metal prior to the metal being poured into moulds. Before the war the cupola had an open top and flames could be seen by enemy aircraft. A covering was provided which it was found, in addition to preventing glare, also arrested grit. Whilst all cupolas were equipped with this dry form of grit arrestor their efficiency was not very high. The electrostatic precipitator, the venturi cleaner and the bag filter, for reasons of cost or from practical considerations, were unsuitable. The Wet Type should be installed in all but the very smallest of installations. With this type efficiencies of 60–70 per cent. were obtainable in arresting grit and dust.

The Wet Type would, in fact remove 100 per cent. of grit above 75 microns in size and also remove 30 to 50 per cent. of sulphur from the gases.

Dr. Albert Parker (Individual Member) said that several speakers had expressed the opinion that there was need for legislation in relation to the emission of oxides of sulphur. The opinion had also been expressed that there should be an authoritative simple rule or guide which could easily be used in deciding on the heights of chimney needed to ensure adequate dispersion and dilution of pollutants in the atmosphere. As an assessor to the Committee on Air Pollution, he knew that both of these questions were fully discussed by that Committee and much was said about them in the Committee's reports published in 1953 and 1954.

The fact was that there were no known practicable methods at reasonable cost of greatly reducing the quantity of oxides of sulphur emitted to the atmosphere from the use of the fuels available in this country, either by removing sulphur from the fuels before or during use, or by removing the oxides of sulphur from the flue gases before discharge. This was no doubt why the Clean Air Act, 1956 dealt only with smoke and grit and dust. The difficult problems of reduction of pollution by compounds of sulphur were under investigation by several organizations.

There was evidence to indicate that the detrimental effects of oxides of sulphur on health and on materials would be less in the absence of smoke and grit and dust than in their presence. This stressed the importance of a determined drive towards applying all practicable methods of reducing the emissions of smoke and grit and dust; by using known methods a very great improvement could be made.

With regard to the heights of chimneys, simple rules could perhaps be applied if the sites of buildings and large areas surrounding them were flat, without hills or valleys, there were no neighbouring buildings at various heights to cause eddies, and there were no natural eddies or downdraughts in the air within a few hundred feet about ground level. As this unfortunately was not the situation in most instances, no rule could be simply applied; the desirable height of any chimney emitting large quantities of pollutants could only be decided by experts taking into account all the local conditions.

G. W. Farquharson, replying to the points raised in the discussion regarding his paper, said he had noted with pleasure the remarks by Mr. G. Nonhebel that the table showing the measurement of smoke from water tube boilers during soot blowing was very similar to results obtained by a committee of the British Standards Institution engaged on such measurement. His written paper was based on factual evidence and practical experience, not platitudes so often resorted to when dealing with air pollution. He had no evidence to support the belief that shorter slicing tools would be the answer to the control of black smoke during such operations. The frequent use of the slice and the resultant black smoke emissions indicated in some cases that the type of fuel was not satisfactory and not the slicing tool.

The suggestion by Councillor W. A. N. Jones to draw soot out of the furnace by suction was interesting, but it should be remembered that as far as water tube boilers are concerned, the major operation was the removal of the soot and grit adhering to the tubes and the suction theory would be impracticable, but on the question of encouragement and monetary rewards to proficient boiler men, he was in entire agreement.

He noted Councillor W. A. Beardsley's remarks and agreed that litigation costs could be heavy and quite a burden on small local authorities, especially when High Court decisions were involved, but he suggested that for the average case regarding contraventions of Dark Smoke emissions under the Clean Air Act, 1956, if the evidence of any local authority was sound, and proved that the contraventions did occur, the cost of such litigation in the Courts of Summary Jurisdiction would not be unreasonable.

On the points raised by Mr. W. H. Wattleworth, whilst recognizing that exemption prevailed in relation to the creation of Smoke Control Areas, he agreed that certain mechanical stokers required supervision, attention, and graded fuel, but the same was applicable to oil fired furnaces now exempted by legislation and therefore he supported exempting mechanical stokers in certain Smoke Control Areas. The paper referred to the provisions in the Act whereby a local authority was enabled to grant a temporary exemption certificate for a prescribed period until alterations to the existing plant or furnaces had been carried out. This called for consultation and co-operation between the local authority and the applicant, and from the experience already gained in Birmingham, the local authority, by acting judiciously in granting such applications, ensured that the likelihood of future contraventions was minimized, and the example quoted by Mr. H. E. T. Lowbridge supported this view.

He reminded Dr. R. Jackson that the paper and tables quoted were based on factual evidence and related to administration under the Public Health Act, 1936. This was done deliberately to show that although this Act was often criticized, by a strong policy of the local authority and a " specialized inspectorate " to carry it out, considerable reduction in excessive smoke emissions was achieved even with the past legislation.

Whilst in agreement with Mr. C. H. Crawford, only time could show whether the other priority matters as enumerated in the paper and now exercising the minds of all local authorities would result in the acceptance, or otherwise, of the responsibility placed upon them by reason of the Clean Air Act, but he would support Mr. Crawford's opinion that credit should be given to many industrialists who had already put their plant in order.

N. Bastable, replying, said that it might well be, as Mr. Goodfellow had suggested, that there were special circumstances in Leeds which influenced the concentration of SO_2 and that all areas were not alike in topographic, geographic and climatic conditions. Men, however, were alike everywhere, and what would poison a man in Leeds would poison a man on the Great Orme. He did not suggest that they needed a national standard for the maximum allowable concentration of SO_2 from each individual source, but that they should have a standard for the total concentration at ground level.

This would mean that the concentration arising from a new source, when added to the existing background concentration in any area, should not exceed the standard set.

There should be Government research into the problem so that local authorities might receive advice as to the desirable standards of SO_2 concentration. It would be impossible for each area to decide its own standard because local authority needs would not warrant the employment of consultants.

Mr. Draper had made the point that the concentration of the sulphur oxide on a nucleus of carbon might be the source of the ill-effects. This would explain the apparent diversity of views as to the threshold of dangerous concentrations. The obvious solution was to reduce atmospheric pollutants of all descriptions, whether by higher efficiency, interception, or dispersal in the upper atmosphere. The difficulty of ensuring adequate dispersal by the use of tall chimneys was that owing to town planning considerations it was not always possible to build them high enough. Other remedies had then to be sought.

Forum on Smoke Control Areas

Reports from the Society's Divisions

SCOTLAND

(*By John Innes*)

LOCAL authorities north of the Border have been somewhat slow in submitting proposals for the formation of smoke control areas, but the City of Edinburgh has led the way and one area has been confirmed by the Secretary of State for Scotland. The Burgh of Dumbarton is awaiting confirmation of an area, which may be approved by the time this report is read. Proposals for five areas are before the Secretary of State for consideration. Details of the foregoing are as undernoted.

1. **Smoke control area Order confirmed**
   Authority: Edinburgh
   Area: Sighthill No. 1—138·5 acres.
   Premises: 1,007 domestic, 13 other premises, including schools, shops and offices. No industrial premises.

2. **Order submitted for confirmation but not yet confirmed**
   Authority: Dumbarton.
   Area: No. 1—625 acres.
   Premises: 1,030 domestic, 1 hospital, 1 nursery.

3. **Preliminary proposals relating to specified areas submitted for consideration and approval in principle**
   Authority: Coatbridge.
   Area: Shawhead—acreage not known.
   Premises: 314 domestic, 1 farm. (Site to be developed for housing purposes).
   Authority: Dundee.
   Area: Menzieshill—525 acres.
   Premises: 36 domestic, 10 other premises (Site to be developed for housing purposes).
   Authority: Glasgow.
   Area: Centre of city—201 acres.
   Premises: 236 domestic, 3,449 commercial, 414 industrial, 27 other.
   Authority: Kirkcaldy.

(1) *Area:* Templehall—600 acres.
Premises: 3,977 domestic, 59 other.

(2) *Area:* Links Street—7½ acres.
Premises: 289 domestic, 10 other.

There are, too, a number of smoke-free areas operating under tenancy agreements with the Authorities of Edinburgh, Motherwell, Paisley and the Cumbernauld Development Corporation.

Interest is quickening, as later reports will doubtless show.

NORTH EAST

(*By G. W. Tate, F.A.P.H.I., M.R.S.H., Hon. Secretary*)

THE principal industries in the area covered by the North East Division are coal mining, ship building and engineering, and iron and steel works, and since the mining of coal is substantially carried out in 60 per cent of member Authorities, wittingly or unwittingly, concessionary coal tends to colour the approach to clean air.

Ten Local Authorities have given consideration to the establishment of smoke control areas, some before the passing of Act.

Newcastle City has a smoke control area of 118 acres awaiting an Inquiry, and has three other control areas provisionally outlined, totalling 281 acres, and is enthusiastic.

Sunderland County Borough are proceeding to stage two in an area of 85 acres, and will do everything possible to progress.

Middlesbrough County Borough, Darlington County Borough and Billingham Urban District are surveying potential control areas. Of the remaining five, further consideration has been shelved for a time, or accepted in principle.

The great majority have so far given no consideration to the establishment of smoke control areas even though substantially all post-war houses have the appropriate appliances.

Apart from those odd Local Authorities which are purely residential and who consider no problem exists, there is sufficient evidence to show that concessionary coal and the reluctance to have it interfered with is the stumbling block in 60 per cent of Authorities. Other reasons given, but which are not wholly convincing, are, railway station or engine sheds in centre of area, shipping on river, dislike of smokeless fuels, presumably coke, and also one suspects, " until the neighbouring authority can show some results."

Publicity on the Clean Air Act and its implications, has generally been good, but so long as the other chap has to clean the air, most people agree with it but become apathetic when it is suggested that it is a personal problem.

Local Authorities generally reflect the attitude of the general public, when it would perhaps help towards clean air much more if the public reflected the attitude of the Local Authorities.

The cost involved in conversions is advanced as a reason for not facing up to the problem, when it might be more realistic if it was said that the domestic contribution was not going to be tackled until industry, whom some consider the major contributor; has been cleaned up.

All the authorities in the division with the odd exception have adopted the Building Byelaw. Virtually all the post war council houses have the appropriate fuel burning appliances.

No authorities can plead ignorance of the Clean Air Act and what it can do.

Two thirds of the authorities are faced with the problem of miners' concessionary coal, the adjustment of which they rightly claim is outside their jurisdiction, and as miners serve on the Local Authority they are unlikely to take a positive line if it implies any interference with free coal.

The great needs to be settled before progress can be seen are—a steady stream of publicity of the right kind, education—visually as well as orally—for the school leavers as well as adults, a reduction in the price of smokeless fuels, reliable and regular information on the quality and performance of all iypes of equipment and fuels from an tndependent body, and so far as this Division is concerned the freeing of the shackles which bind it to one meeting per year while allowing freedom to all other Divisions.

The Local Authorities in the Division are divided into three areas, and meet as such to discuss smoke abatement problems and take such uniform action against the atmospheric pollution as is demanded by the situation.

The Teeside Committee has been functioning since 1950 and through regular meetings, intensely keen Local Authorities and Officers, has made a marked progress in an area where the problem is as diverse as it is extensive covering as it does iron and steel, ship building and engineering, docks and shipping, chemicals, etc.

The Tyneside, and the Wearside Committees have only recently come into being, and are in the midst of teething troubles. They are, however, emerging from the formative stage and with enthusiastic Officers, can find ample scope for their energies, and secure that degree of co-operation between Local Authorities so essential to a successful prosecution of the case for clean air.

NORTH WEST

(By A. E. Snodgrass, F.R.S.H., F.A.P.H.I., F.I.P.H.E.; C.P.H.I., Bury)

WHEN considering progress in the establishment of smoke control areas in the North-West we are immediately reminded that this is the area in which administrative control of smoke emission was first created. Indeed certain public spirited citizens of Manchester around the turn of the century founded one of the two pioneer organizations from which the present Society springs. We are proud to recall and honour the services of men of the calibre of the late Will Melland and our Director. We also recall with pride that one of the founders and former Chairman of the Society, the late Charles Gandy of Manchester, first introduced the subject of controlling the emission of smoke within geographical areas, having regard to the direction of prevailing winds, in a letter written to the *Manchester Guardian* in 1933. This created considerable interest and controversy which was reaching a crescendo on the outbreak of the late war, to be revived in 1946, and before 1952 some seventeen local authorities throughout the country had acquired powers under Local Acts to establish smokeless zones. Of these, eight (Manchester, Salford, Bolton, Rochdale, Preston, St. Helens, Crewe and Urmston) are situated in the Division.

Smoke Control

It will be appreciated therefore that the operation of the Clean Air Act on 31st December 1956 found the foregoing authorities committed to certain programmes under their Local Acts which had to be re-oriented to the provisions of the new Act. Therefore progress in the establishment of smoke control areas within the Division must first be considered in terms of smokeless zones. It is gratifying to report that at present there are in operation twenty smokeless zones and eight smoke control areas, in nine local authorities comprising over 11,000 premises and a total area approximately 1,500 acres. Fifteen of these areas are situated in the City of Manchester, whose first smokeless zone became operative on 1st May 1952. Also included are two urban district councils with populations under 26,000 (Denton and Audenshaw) who have established smoke control areas in respect of newly built council houses and council houses yet to be erected. Prestwich M.B. has also established a smoke control area in respect of newly erected council houses and in the other authorities (Liverpool, Salford, Preston, Bolton and Rochdale) the areas include central sites of mixed development, council housing estates and redevelopment of clearance areas. Liverpool, Rochdale and Denton together with Ellesmere Port M.B. and Chadderton and Royton U.D.C.'s have also received preliminary Ministry approval to a further nine smoke control areas comprising 5,582 premises in another 1,500 acres, mostly comprising newly built council houses or houses (council and private) to be erected.

It is perhaps appropriate at this stage to mention that more than one third of the 178 local authorities responsible for enforcement of the Act in the Division have taken some administrative action to enforce its smoke control provisions ranging from action to establish smoke control areas to the mere adoption of the amendment to local building byelaws to ensure that all firegrates and heating appliances in newly erected premises are of approved smokeless combustion design.

Sixteen local Councils have proposals in hand, which have been resolved in principle, to establish 32 smoke control areas comprising a further 26,790 premises of all types. These include an area of 23½ acres containing 220 varied premises, in my own authority who are establishing a smoke control area in connection with the re-development of three clearance areas. In this connection it will be necessary to provide financial assistance in connection with the conversion of domestic firegrates in 170 remaining dwelling houses. Blackburn C.B.C. also has an interesting development pending, in connection with the declaration of a smoke control area associated with the re-development of a site at present containing 700 dwelling houses and other premises.

Seven other local authorities have established voluntary smoke control areas by means of tenancy conditions in Council houses and many more Councils have resolved to impose similar conditions in respect of houses yet to be built.

A further twelve authorities have indicated that they are in favour of establishing smoke control areas within their districts at some appropriate time still to be determined. One of these authorities (Oldham C.B.C.) has ear-marked a sum of £1,000 for the establishment of an initial area.

This review would be incomplete without some reference to the Urmston district heating scheme. In 1947 the Urmston U.D.C. installed this scheme in connection with a number of housing estates comprising 409 premises and thereby established one of the earliest smoke control areas in respect of Council estates in the country. Now this scheme along with 2,865 other houses is to be included in a smoke control area under the Act.

To sum up, it will be noticed that smokeless zones or smoke control areas have been adopted or are about to be adopted by 28 Councils, comprising a representative cross-section of every type of local authority within the Division. These areas vary considerably in acreage and in the numbers and types of premises included therein from central areas to periphery housing estates, and domestic, factory, office, warehouse and social premises and public buildings, dispersed throughout industrial Lancashire and Cheshire. Manchester has pioneered every aspect of such schemes, including the imposition of tenancy conditions regarding smokeless fuels in houses in their " overspill " areas outside the City boundaries. In some cases the smaller county districts receiving such " overspill " have assumed the initiative and informed the City Council that they considered action should be taken in conformity with schemes in hand in the " receiving area." Liverpool also has imposed similar conditions in houses on their " overspill " estates. Some local authorities have decided to establish smoke control areas in association with slum clearance and town planning schemes. None appear to have been deterred from their intentions by the cost of installation or conversion of smokeless appliances in domestic premises. In this connection the early experience of Bolton C.B. in their first smokeless zone, previously reported elsewhere, will be of utmost value to all concerned.

Problems

Obviously such progress cannot have been achieved without encountering difficulties to be overcome. Generalizing, no real difficulties appear to have been encountered in the establishment of smokeless zones or smoke control areas in central city zones with small domestic populations, where invariably, office and other premises were previously equipped with means of consuming approved fuels, or in defining areas in respect of future housing estates or the re-development of clearance or improvement areas. The greatest difficulties appear to have arisen where existing housing estates have been defined as smoke control areas, either statutorily or voluntarily. The first point to be considered is how many houses already possess the necessary appliances, how many require firegrate conversions, are they all serviced with gas to facilitate ignition points. In common with other Divisions the consensus of opinion in the North-West is that jet ignition is preferable to gas pokers. Finally has sufficient accommodation been provided to each house for the storage of solid smokeless fuels. Some existing housing estates are not serviced with gas and the provision of such service increases the cost of firegrate conversions, although the merits of Calor gas and battery pokers must not be ignored.

The over-riding consideration to be resolved before embarking on the establishment of any smoke control area is the local availability of smokeless fuels. This has now been adequately dealt with in the Memorandum of the Ministry of Housing and Local Government, but previously, one authority, Salford, had the experience of failing to secure confirmation of a smokeless zone order because of the failure to satisfy the Minister that sufficient fuels were available to meet demand. The same authority has subsequently reported difficulties during the winter of tenants not receiving regular supplies of coke even after fortnightly deliveries have been arranged with the merchants and Gas Board. Presumably the fortnightly delivery had been agreed as a means of ensuring supplies and minimizing storage difficulties. The same experience is reported from Bootle, who also report a public prejudice against the use of coke as a domestic smokeless fuel and particularly against the retail price of such fuel. Rochdale and Crompton U.D.C. report cases of public objection to the installation of gas services, presumably to premises not previously serviced, to provide means of ignition to solid smokeless fuels. From West Cumberland come reports that the particularly poor availability and distribution of solid smokeless fuels in that area have prevented local authorities from giving any serious consideration to the establishment of smoke control areas. Representatives of Urmston U.D.C. have reported previously that one of the disadvantages of their district heating scheme is that it deprives the domestic household of the use of a firegrate, which can be so necessary in times of sickness and for other domestic uses. Three local authorities (two county boroughs and a county district) in the South Lancashire coal field have reported that the existence of miners concessionary coal has influenced them in delaying the establishment of smoke control areas. These Councils direct attention to the re-purchase price of such coal paid by the National Coal Board (two shillings per cwt.) which compares unfavourably with the retail price of solid smokeless fuels in their areas, and accordingly public support for smoke control is unlikely to be forthcoming.

Public Reaction

In general the public reaction to smokeless zones, smoke control areas and other smoke control measures in the Division has been favourable. No really serious or highly organized opposition was encountered in the establishment of existing zones and areas. Indeed, it has been fairly common for more recent smoke control areas to encounter little or no opposition. Bolton had the unique experience of suffering from some suspected organized political opposition amongst householders after a smokeless zone, which had been confirmed without enquiry in the absence of objectors, became operative. This authority, Salford and Rochdale have had resource to successful legal proceedings on occasion in respect of smoke emission in their smokeless zones, whereas Manchester have successfully established and administered their numerous zones and areas without resource to such action.

Propaganda

Doubtless this successful and co-operative progress within the Division could not have been achieved without a large measure of public support. Commencing with the London "smog" incident of December 1952, public interest in smoke control has progressively developed favourably and the subject has been topical with all sections of the national and local press. In addition, those authorities who have established zones or areas or seek to establish areas have realized the advantages of effective publicity campaigns and demonstrations of smokeless fuels and appliances. In these they have been, and will continue to be, admirably assisted by the national utility services and manufacturers of smokeless fuels and appliances. This fact was confirmed by the success of the seven months propaganda campaign concluded last March in which forty local authorities in South-East Lancashire and Merseyside co-operated with the joint sponsors, the national utility services, fuel and appliance manufacturers and other exhibitors. Of these, thirteen local authorities, who previously had not taken such action, have initiated proceedings to establish smoke control areas within their districts.

YORKSHIRE

(*By James Goodfellow, M.R.S.H., Hon. Secretary*)

(1) Summary of the Action Taken or Being Considered by Local Authorities

THE total number of authorities returning information in this report is 47. Eighteen of these authorities have decided in principle on the property within their boundaries which is to be included in smoke control areas. The number of areas so far decided in principle is 29. Nine authorities have decided in principle on one smoke control area, seven authorities have decided in principle on two smoke control areas, and two authorities have decided on three smoke control areas.

Twenty-six authorities have taken no action at all in regard to smoke control areas, and six of these have decided not to take any such action.

Three authorities have taken no action so far, but have the matter under consideration.

Eight proposed smoke control areas have received the Minister's provisional approval. Detailed surveys of proposed smoke control areas, that have received provisional approval, have been completed or are in progress in six cases. One smoke control area has been confirmed by the Minister at the time of writing, and this order is in respect of a new housing estate at Ossett.

(As distinct from smoke control areas made under the Clean Air Act, 1956, 20 smokeless zones made under a Local Act have been made, confirmed and are in force in Bradford. These smokeless zones cover 1,481 acres of the Central Area and 19 housing estates.)

(2) Information as to Features of Unusual Interest

In the case of one authority which has proposed to establish two smoke control areas, the property in one of the areas is almost exclusively council owned, and in the other, practically all privately owned. The council owned houses are equipped with old Yorkshire type ranges, and the privately owned houses, having been built before 1935, do not contain suitable appliances. Consequently, in both cases, nearly all the existing appliances will have to be replaced by modern smokeless appliances.

In the case of another authority, the proposed smoke control area has within its bounds a hospital which is Crown property; there is also some land on which private houses are likely to be erected, which will have to be fitted with suitable smokeless appliances. There are no industrial premises included in this area.

A further interesting case is a declared smoke control area, within which lies a slum clearance area which is to be re-developed as flats. Agreement has been reached with the Housing Committee to include the re-development area in the smoke control area.

In the case of one authority, which so far has not decided in principle on any smoke control area, there is a predominance of back-to-back houses. In this case special consideration is being given to fireplace conversions in sub-standard property.

Three of the authorities who have decided to take no action in regard to smoke control areas, give as their reason that they are satisfied that there is no smoke problem in their respective areas. The council of one of these authorities has refused to make a byelaw requiring installation of smokeless appliances in new dwellings.

In the case of one authority which has decided in principle on two smoke control areas, the first of these areas takes the form of a post-war housing estate which is only partly completed and will allow all future developments therein to be controlled with respect to smoke production. The second of the two areas contains the domestic and service buildings of an R.A.F. station and industrial premises adjoining. This same area also includes all the buildings of a civil airport; a great deal of land scheduled for agriculture and several sites on which housing developments may take place.

In one case where a central smoke control area has been decided in principle by the authority, several points of interest have arisen. One of these relates to the Garchey System of refuse disposal which serves two large groups of blocks of flats; it is proposed that the building housing the Garchey incineration plant should be exempted. A second point of interest is the saving in cost of £8,845 on 347 ranges which may be made possible by the use of a conversion unit proposed to be made by a firm of appliance manufacturers. It will also be proposed that a new boiler plant which is to be installed at a university for carrying out research into the question of atmospheric pollution, shall be exempted from the smoke control area when being used on such research projects.

(3) Special or General Difficulties

The main difficulty being encountered in the Yorkshire Division arises from the problem of miners' concessionary coal. Most of the authorities within the Division are coal mining districts. Until the difficulties inherent in this problem have been finally settled at national level and an acceptable solution been found smoke control areas will remain impracticable in the mining areas. Not only are the mining fraternity financially affected by this question, but also many of the councillors are connected with the industry, and it is stated that they also would be likely to suffer financially by the setting up of smokeless zones.

Other various difficulties have been reported. Two authorities give the shortage of technical staff as the greatest drawback. One authority experienced difficulty in gathering information in an area survey due to the reluctance of some members of the public to co-operate. Some authorities have met resistance from the public as to the use of smokeless fuel, particularly from older people who say they prefer the bright cheerfulness of a coal fire. Another authority is of the opinion that lack of storage space for smokeless fuel will be a major obstacle. One authority has met some anxiety as to the destructive effect of coke on copper fire-back boilers. Part exemption or non-exemption for various industrial concerns is stated to be a vexed question with some authorities.

Several authorities are of the opinion that their procedure is at too early a stage for them to have met all the real difficulties that are likely to arise.

(4) State of Public Opinion

In the large conurbations, public opinion is decidedly in favour of central smoke control areas.

In the mining districts, public opinion generally is against smoke control areas, due to the problem of concessionary coal.

Strong views are held by large sections of the public on the price of smokeless fuel. This of course is higher per unit of weight than the price of coal, and many consider that they should not be made to pay this high price.

Some authorities state that the public will not accept the provisions as to domestic smoke until industrial smoke has been fully dealt with.

Some members of the public are apprehensive about the use of gas because of the danger of explosion on ignition.

There is some concern that the promotion of smoke control areas may give some help to oil which is imported and mitigate against coal which is indigenous.

(5) Attitude of Local Authorities

It is interesting to note the very high percentage of the authorities included in this report who have shown a keen interest in the problem of smoke control. This is indicated by the number of smoke control areas which have been declared in principle. There are some councils who have not yet made any declarations in principle, but they have shown that they appreciate the need for smoke control areas, and in these cases, had circumstances been different, smoke control areas would have been established. The main reason for this lack of action, once again, is concessionary coal, and if this question is settled, then most authorities would wish to proceed to declare smoke control areas.

There are only six authorities who have taken no action and have no intention of taking any action.

To a lesser degree, in the smaller authorities, finance is another reason for taking no action.

(6) Prospects of Progress

The prospects of progress in the coal mining areas do not seem very promising at the present time.

Prospects of progress in other areas where a start has been made are good. Most of the smoke control areas which have been decided in principle are in the nature of " Pilot Schemes." If these initial smoke control areas prove to be a success, plans for further control areas will be proceeded with. Depending on the success of initial smoke control areas, several authorities state that they intend, eventually, to include their whole district in further control areas.

It would seem that progress in many areas may only be limited by the available supplies of smokeless fuels.

WEST MIDLANDS

(By G. W. Farquharson, F.A.P.H.I., Hon. Secretary)

THE Division includes the counties or shires of Hereford, Salop, Stafford, Warwick and Worcester. On the 9th May, 1858, a questionnaire seeking information on the situation in respect to smoke control areas was circulated to each of the local authority members of the Society situated within the Division and the following report collated from the replies received was authorized by the Divisional Council of the Division. The report shows, under the appropriate headings, the position prevailing on the 3rd June, 1958.

Circulation of Questionnaire

Local Authorities	*Circulated*	*Replied*
County Borough Councils	9	9
Borough Councils..	14	14
Urban District Councils	10	9
Rural District Councils	2	2
	35	34

Summary of Replies from Local Authorities

Number establishing Smoke Control Areas	*Number having the matter under consideration*	*Number taking no action*
17	12	5

Areas Established.—A total of 14 smoke control areas have been established, the total acreage being 1,373·1 acres. In these areas there are 5,908 private dwellings and it is estimated that the total cost of adaptation to the requisite appliances within the dwellings will be £58,257 5s. 8d.

Surveys in Progress.—Twelve local authorities indicated that they are engaged on survey work and five area surveys have been completed.

Type of Areas.—The areas established and those under consideration are mainly domestic in character, only a few of the areas being of mixed development, i.e. domestic, commercial and industrial buildings.

Building Byelaws. — Twenty - nine local authorities in the Division have adopted the amendment to the Model Building Byelaws, Series IV Building (1953) relating to the arrangements in new buildings for preventing smoke.

Smokeless Areas.—Under Private Acts two County Boroughs have established three such areas, the total acreage being approximately 233 acres.

General Comments Received

In one instance a County Borough have approved a policy whereby all areas of new housing development, both municipal and private, will automatically be declared smoke control areas. The same authority has also decided that in the case of a change in the tenancy of an existing post-war council house with appliances capable of burning smokeless fuels, it shall be a condition of the new tenancy that only such fuels are used.

Another County Borough has designated the site of a re-development area as a smoke control area. The area being domestic in character will include multi-storey flats and private properties.

In another instance a County Borough has declared it to be its future policy to designate the central re-development areas as smoke control areas. The total acreage in this case being approximately 1,382·5 acres, consisting of mixed development.

Public Opinion

There is no yardstick whereby this can be measured. The press throughout the Division have given support to local authority activities in regard to the creation of smoke control areas. Assuming the action of local authorities in this matter is a reflection of public opinion, then from the replies received from the members whereby approximately 90 per cent. have considered establishing smoke control areas and 60 per cent. of this total have reached agreement in principle, public opinion may be considered as favourable.

EAST MIDLANDS

(*By Alfred Wade, M.B.E., F.R.S.H., Hon. Secretary*)

IN order to ascertain progress so far made with smoke control areas in the East Midlands, a questionnaire was issued to 129 local authorities on the 2nd May, 1958. Sixty-nine replies were received.

1. Summary of Action Taken or Being Considered

In only twelve local government areas is progress reported (three county boroughs, five boroughs, two urban districts and two rural districts). The information received may be summarized as follows:

1. *County Borough* (Nottingham):

(*a*) A smokeless housing estate comprising approximately 1,000 acres and 6,500 houses, together with associated schools, shops, industrial buildings, etc. Smokeless conditions enforced through tenancy agreements, leases, etc.

(*b*) Proposal by the Council to establish a smoke control area in the City Centre has received preliminary approval by the Ministry of Housing and Local Government. The area comprises 57·6 acres and 468 offices, 308 shops, 84 factories, 88 houses, etc.

2. *County Borough* (Leicester):

(*a*) An order declaring a re-development area to be a smoke control area will operate from the 1st September, 1958, and will comprise 27·4 acres and 752 dwellings, seven shops, two public buildings and one factory.

(*b*) A central area of 44 acres comprising 514 commercial, industrial and public buildings is to be declared a smoke control area.

(*c*) Additional proposals are under consideration.

3. *County Borough* (Grimsby):

(*a*) Three commercial or industrial areas totalling 200 acres to become a smoke control area in 1959.

(*b*) One partly-developed residential area of 1,135 acres to become a smoke control area in 1960.

4. *County Borough* (Derby):

A smokeless housing estate comprising 597 dwellings and six shops has been established under tenancy agreements. Extensions are now under consideration.

5. *Borough* (Mansfield):

Consideration is being given to the declaration of a smoke control area of 159 acres comprising a new housing estate.

6. *Borough* (Grantham):

The next new housing estate to be erected by this local authority may be declared a smoke control area. Details not yet available.

7. *Borough* (Chesterfield):

Two areas are to be surveyed—one in town centre and the other a new housing estate.

8. *Borough* (Scunthorpe):

One area surveyed with a view to being declared a smoke control area comprising a newly built residential area of 313 acres and 237 houses.

9. *Urban District* (Long Eaton):

A housing estate in course of development to be a smoke control area comprising 57 acres and 750 dwellings.

10. *Urban District* (Corby):

This Council has agreed in principle to declare two smoke control areas. Both are partly developed but the major parts have still to be built (about 500 acres and 4,500 properties, mainly dwelling-houses).

11. *Rural District* (Chesterfield):

Preliminary surveys of three potential smoke control areas have been carried out and positive action is to be taken in respect of one area comprising 321 acres and 406 houses and 15 other properties.

12. *Rural District* (Shardlow):

It has been decided to establish smoke control areas on three proposed housing sites. Details not yet available.

2. Information About Any Feature of Unusual Interest

In this survey it was of interest to note that in the East Midlands two rural districts have taken positive action with a view to the establishment of smoke control areas.

3. References to Any Special or General Difficulties Being Encountered

Twelve local authorities in mining areas refer to the concessionary coal arrangements for miners. This appears to be a major problem in mining districts and it is suggested that no real progress will be achieved until a satisfactory national agreement on the subject has been reached.

Pollution from the iron and steel, brick and limestone industries is causing concern to some local authorities in districts where those trades predominate. The establishment of smoke control areas may be delayed until solutions are found to these special problems.

Several local authorities express concern at the shortage of qualified Public Health Inspectors to undertake the administration of the Clean Air Act.

4. Comment on the State of Public Opinion and the Attitude of Local Authorities and Others

From information received, it appears that there is considerable apathy on the part of the public and local authorities towards the establishment of smoke control areas and so far as can be ascertained, only twelve local authorities in the East Midlands have so far taken any action in the matter. If there is to be an 80 per cent. reduction in atmospheric pollution during a period of fifteen years, as visualised by the Beaver Committee, local authorities must be more energetic in the establishment of smoke control areas. It is clear that without compulsion, smoke abatement will not readily be accepted by the public. It must also be emphasized that domestic chimneys are responsible for about 50 per cent. of the pollution and it is regrettable that many thousands of houses erected in post-war years, although equipped for smokeless operation, continue to give off pollution from bituminous coal fires.

Many local authorities, mostly in rural or coastal districts, declare that they have no pollution problems and that no action is called for. Such authorities do not realize how much can be done to deal with domestic smoke.

5. Prospects for Progress

Replies from 43 local authorities indicate that the prospects for progress are " nil." It is discouraging to find that in the majority of local government districts little or nothing is being done. Every local authority should consider the establishment of a smoke control area and should realize that a small beginning in this respect may be of great value in moulding public opinion in support of clean air.

SOUTH EAST

(*By J. J. Matthews, M.A.P.H.I., Hon. Secretary*)

A QUESTIONNAIRE on smoke control areas during the latter part of 1957 was addressed to all local authorities in the area of the Division, except non-member rural councils.

Of a total of 280 forms sent out, 220 were returned and indicated that 136 local authorities had considered the matter, 73 having decided to take action. These included 21 Metropolitan Boroughs, 20 other authorities within and 32 outside the Metropolitan Police District.

Up to the 21st July smoke Control areas have been confirmed in respect of six Metropolitan Boroughs and submissions to the Ministry of Housing and Local Government await confirmation in five cases.

Confirmed

Metropolitan Boroughs

Fulham:	100 acres—residential.
Stoke Newington:	150 acres—residential.
St. Marylebone:	132 acres—2,862 premises.
Bermondsey:	34 acres — London Bridge area.
Westminster:	60 acres—Temple Bar area.
Woolwich:	26 acres—residential.
	212 acres—New housing estate.

In one local authority in the Metropolitan Police District (Hayes & Harlington) five areas have been confirmed, and two local authorities (Tottenham and Hayes & Harlington) await confirmation of their submissions and further submissions.

Confirmed

Hayes & Harlington U.D.:

5 areas .. .. (Mainly open space)	240 acres	
	350 ,,	
	265 ,,	
	440 ,,	
	376 ,,	
Approx.	1,671 ,,	Total

Outside the Metropolitan Police District, two local authorities (High Wycombe and Oxford) have had confirmation of a total of six areas.

High Wycombe M.B.:

5 areas .. .. (New housing estates)	11·75 acres	
	56·60 ,,	
	10·65 ,,	
	10·90 ,,	
	39·00 ,,	
Approx.	128·9 ,,	Total

City of Oxford:

17·3 acres—in the town centre.

Further to the foregoing, 22 local authorities have made informal proposals to the Ministry as to 27 areas.

The various stages of consideration, informal proposals and official submissions to the Ministry show a lively interest in the subject of smoke control areas by a total of 55 authorities.

Apart from these implementions of the Clean Air Act, 1956, the whole of the City of London and an area in Tottenham have been declared smoke control areas through private Acts of Parliament.

Co-ordinating Schemes

Discussions are taking place among 28 local authorities with a view to co-ordinating schemes for the formation of 40 smoke control areas.

In West London an Inter-Borough Smoke Control Liaison Committee has been formed with the object of co-ordinating the efforts of the constituent councils to implement the provisions of the Clean Air Act, 1956, in particular those relating to smoke control areas.

The Metropolitan Boroughs of Fulham and Hammersmith, the Boroughs of Acton, Barnes, Brentford & Chiswick, and Willesden are represented on the Committee, and information has been given for publication, to the National Society for Clean Air.

On the evening of the 24th April, the undermentioned statement was broadcast over the B.B.C.'s sound and television news services:

> " At Hammersmith the Council have approved in principle a plan to make the whole of the Borough a clean air one within the next ten years. The scheme will be carried out in stages. The first area to be made a smoke control area will be the southern part of the Borough. There will then be a clean air barrier stretching north and south across west London. This is the first outcome of co-operation between the Boroughs of Hammersmith, Fulham, Willesden. Acton, Chiswick and Barnes."

Note: A plan showing the first area in Hammersmith to be dealt with was shown at the end of the broadcast on television.

The Committee is meeting regularly and a press conference is being arranged in the near future as part of an extended scheme of publicity.

A Joint Conference of representatives of local authorities has met at the Town Hall Leyton to discuss matters of common interest in regard to air pollution in the districts concerned, and to give preliminary consideration to the possibility of joint action in regard to any proposals for the creation of smoke control areas therein.

The local authorities taking part were the Metropolitan Boroughs of Hackney, Poplar and Woolwich; the County Boroughs of East Ham and West Ham; the Boroughs of Barking, Dagenham, Ilford, Leyton, Walthamstow and Wanstead & Woodford.

The first meeting of the Conference was also attended by a nominated representative of the Ministry of Housing and Local Government, Mr. P. J. Herrop, and of the London and Home Counties Clean Air Advisory Council—Mr. H. G. Clinch, M.B.E.

Councillor F. W. Marshall (Leyton) summed up the discussion and said that while he noted suggestions for caution in pursuing plans for smoke control areas, he personally advocated persistence in this matter in view of the high cost of air pollution in terms of money and human lives and suffering.

Leyton would press ahead with plans for the establishment of their first smoke control area, and hoped the other local authorities represented would not allow themselves to be put off by the difficulties which had been mentioned. They should keep together and continue to share their views and experiences.

The Conference is due to meet again in October of this year.

The need for co-ordination and fully combined interests is obvious when it is considered that atmospheric pollution has no bounds.

There are many districts of course which disperse smoke and grit on prevailing winds to other districts, and this is disposing to delay local action by local authorities at the receiving end.

It seems to be a concensus of opinion that there is much uncertainty as to the availability of sufficient supplies of solid smokeless fuels, and not everyone readily accepts the statement made by the Ministry to the effect that where smoke control areas are confirmed, this will be consistent with solid smokeless fuel availability.

A point has been made here that such priority will react to the deprivation of those outside smoke control areas who seek to benefit by the use of solid smokeless fuels by choice.

The greatest difficulty appears to be the convincing of the public of the need for smoke control, particularly in relation to the domestic use of fuel. There is the utmost need for the fullest publicity on the desirability of the use of smokeless fuels.

Those who had been provident and made voluntary arrangements not to use coal domestically soon realized the advantage economically and appreciated the high degree of labour saving.

Notwithstanding what has been achieved as shown in this statement, it may well be that many local authorities are deterred from immediate positive action through consideration of financial commitments, and there are of course staffing difficulties, particularly in the larger urban and industrial districts.

However, there appears to be good reason to look forward to general progress through the not too distant future to a higher standard of clean air and consequent benefit to the health and general welfare of the people.

THE SOUTH-WEST

(By F. J. Redstone, F.R.S.H., F.A.P.H.I., for the Bristol and West Clean Air Committee)

THE question of establishing smoke control areas has received a great deal of attention by local authorities in the South-West of England, and although it is understandable that this part of the country which generally does not suffer heavy atmospheric pollution has not submitted many schemes under Section II of the Clean Air Act, the possibility of preventing additional sources of pollution in new development has not been overlooked. To this end some local authorities are considering the application of smoke control area procedure to new industrial and residential estates and many have already adopted the bye-law which requires new premises to provide approved fuel burning appliances.

So far as can be ascertained, the cities of Bristol and Exeter are the only places in the South-West which have taken active steps to establish smoke control areas. Bristol has received provisional approval from the Minister for a central smoke control area of more than 200 acres in extent. This area exhibits a cross section of all types of development—industrial, commercial and residential. It is felt that the position of the first area is a good one as its situation will foster civic amenity and at the same time act as a focal point of improvement which will be seen by the majority of its citizens. A detailed survey of the area is in hand and response of the general public to the scheme appears to be very favourable.

In Exeter the City Council has proposed three smoke control areas but to date these have not received Ministerial approval. Two of the sites are being developed by the Council for housing purposes and the other is being developed by private enterprise.

The Bristol and West Clean Air Committee held a conference at the University of Bristol on smoke control areas to which all interested local authorities in the south-west were invited and in addition much literature and other information has been circulated on the value of smoke control area procedure.

Discussion

A. E. Snodgrass submitted the following written addendum to his report from the North West Division:

Since the publication of the Report, three other local authorities, Stockport C.B.C., Ashton-under-Lyne M.B., and Crompton U.D.C., have submitted Smoke Control Orders to the Minister of Housing and Local Government for confirmation. These make a total of twelve local authorities within the Division who have initiated statutory action to implement 40 Smoke Control or Smokeless Zone Orders within their Areas. Six of these local authorities are county Districts. The Stockport area comprises 1,096 premises in 73 acres.

One local authority, Ellesmere Port M.B., has now received Ministry confirmation to an area of 826 premises previously submitted for prior approval.

The Manchester City Council have recently agreed in principle to define a Smoke Control Area at Wythenshawe of five square miles involving 18,000 premises. The estimated cost of inaugurating this Area, believed to be the largest of the kind yet proposed, is £350,000.

The City of Liverpool now has eight

Smoke Control Orders in various stages of operation or implementation.

Dr. Llywelyn Roberts (M.O.H., Sheffield), prior to the opening of the general discussion, reviewed the Divisional Reports, as follows:

The Clean Air Act like all Public Health legislation is long term in its approach and it depends like all health legislation upon the education of the public for its full acceptance; the educative power of Acts of Parliament has never really been fully appreciated. Despite all our hopes and our efforts, the Clean Air Act will take a long time to be really effective and so every opportunity of educating the public as to its value should be taken. Progress becomes cumulative, the value of example becomes increasingly important, and the timorous approach of today becomes the clamant demand of next year—or the year after. The same thing has happened before—the costs of piped water supplies and drainage were always being raised to avoid taking action—and the same is happening about the Clean Air Act.

Much of the machinery of the Clean Air Act may be difficult for laymen to understand, but the conception of a Smoke Control Area is a good one and has the value first of achieving its object of cleaning the air and is also an important educative measure and example of what can be done; it is a clear symbol of the Act's intention. This part of the Act dealing with Smoke Control Areas must, however, be considered in connection with the Act as a whole, for the parts of the Act hang together, and decisions of policy followed in Smoke Control Areas have repercussions in other sections, *e.g.*, the overall cost of administering the Act and also the questions of exemptions.

This is ' an Act to make provision for abating the pollution of the Air.' By its description it is not the final word and the legislation will become increasingly insistent on trying to achieve the goal of a pure atmosphere.

This session of the Conference is concerned with Smoke Control Areas, under powers exercised by borough, urban and rural areas so all types of local authorities are involved—it is dealt with in Sections 11–15, and these have been well summarized in the Clean Air Year Book:

" SS. 11–15 concern Smoke Control Areas, which may be established by local authorities under an Order requiring Ministerial approval. Smoke control areas may be entirely smokeless (as with smokeless zones) or may make certain exemptions or impose special conditions. For domestic (and charitable, etc.) premises local authorities may make a grant towards the cost of converting grates, etc., to appliances suitable for smokeless use. The authority may recover part of the grant from the central Exchequer, and normally the cost of conversion will be: Owner or occupier and local authority, 30 per cent. each, Exchequer, 40 per cent.

" In a case of smoke emission in a control area it is a defence if an authorized fuel only was being burned. Regulations defining authorized fuels have been issued. (Stat. Inst. 1956, No. 2023)."

The various steps in the process of promoting a smoke control area—the decision in principle, the extent and content of the area—whether to include industry and if so how to deal with it; the Minister's acceptance, the detailed survey, the adequacy of suitable fuel and the financial implications, the Order itself, and the work that follows in dealing with the adaptations and the giving of advice and encouragement—are all known to the audience. The various Divisions have been asked to report their progress. This, as expected, has been very uneven, although there is a marked similarity as regards the difficulties encountered. Obvious progress has not been spectacular, although the South East, which has good cause to remember the effect of fog, have been very active, and the North West, which can rightly claim a proprietary interest in this work, has a good and enthusiastic report. The report from the North

West Division, which you have read, contains an account of the steps taken and the difficulties encountered.

As this meeting is one to ventilate the problems and to seek mutual assistance, I would perhaps occupy my time best by mentioning the difficulties and frustrations met:

1. The belief among many local authorities that they have no problem at all, or are said to be awaiting a move by their neighbours.
2. Uncertainty about the cost. Few surveys deal with this, but I am sure that it is exercising the minds of a number of authorities—some small authorities may have very big problems, and may have to incur a proportionately large expense, for the cost of conversion may fall heavily on small authorities who own large housing estates which are equipped with old types of appliances for burning solid fuel. It is heartening to understand from the North East that their authorities have not been deterred by the cost.
3. Cost and availability of smokeless fuel.
4. Storage and the problems of lighting up.
5. Public prejudice and, in some cases, organized opposition.
6. Inadequacy of the Staff.
7. Concessionary coal; this is a major and thorny problem, but it is one that will have to be settled.

There are other very interesting but local problems which will undoubtedly be mentioned during the discussion. It is pleasant to be able to say that no one has complained of any delay centrally in settling any problems. I think we can all commend the Ministry on the sense of urgency that in general prevails in dealing with the Clean Air Act.

Propaganda and public relations

It is undoubtedly true that the impact of the Act on the public has not yet been felt and many reports speak of the need for ensuring that it is effective despite the fact that schemes for cleaning the air are to many persons a nebulous conception and a break with old established tradition. Other divisions speak of the need for co-ordinating effort.

In general the reports are encouraging and, to sum up, it seems to me that there is a general agreement on the need for co-operation, for persistence, for taking long views, and for not being afraid to take big decisions.

Councillor Dr. H. K. Ashworth (Chairman, St. Marylebone Borough Council Clean Air Sub-Committee) said that the first smoke control area in St. Marylebone had come into action the previous day and that Ministerial approval had been obtained for a second, and a survey undertaken for a third. He referred to a point raised as to staffing difficulties for making a survey and stated that in St. Marylebone this had been overcome by the employment of temporary labour. He also stated that one of the difficulties that had been encountered was that the installation of gas into premises where it was not already laid on did not rank for grant. Another source of irritation was the difficulty in persuading domestic coal users to make a change when, as in St. Marylebone, they had two sources of atmospheric pollution which were nationalized, namely, an electric power station and a main line railway terminus and goods yard.

Councillor E. W. Cook (Strood R.D.C.) said that much had been said on the lack of publicity on clean air and, in view of the Diamond Jubilee of the Society in 1959, he suggested to the Executive Council that the time would be ripe for the holding of a National Clean Air Week, whereby the Government, the Society and Local Authorities should combine to make the nation Clean Air Minded. Further, he suggested to the Society that they should approach the Motor Manufacturers Association to standardize the point of emission of exhaust gases from Diesel vehicles, in order to avoid the obnoxious clouds of black smoke that were belched forth. He further suggested that it was possible for those gases to be directed onto a baffle so as to disperse them in a more even form, and relieve pedestrians and motorists alike.

Councillor C. L. Brimelow (Warrington R.D.C.) asked the Panel what steps were being taken to combat the sulphur emitted from chimneys in large housing estates using smokeless fuel. He also asked about the price of smokeless fuels and what was being done to improve their quality.

He referred to that morning's *Daily Express*, which printed a letter stating that the writer had paid £12 or £13 per ton for smokeless fuel, half of which was left unburned in the grate.

Miss Dorothy Boyd (Individual Member) said she observed that that hardy annual, " dissatisfaction with the price of coke " was flourishing again.

She had always understood that it was necessary for coke to be sold at an economic price, otherwise the price of gas and other products of carbonization would correspondingly rise. She therefore suggested that this nettle be grasped in another manner.

Solid smokeless fuels burned in the right appliance, correctly fitted, effected economies. It was necessary to stress that it should be the right appliance correctly fitted, whether it be the domestic boiler, the closed stove, the convector fire, or the modern, overnight burning fire, the efficiency of the latter being greatly improved by the addition of a flue-control plate. It was interesting to note that in the South East Division the City of Oxford was including the flue-control plate in the items qualifying for the grant for necessary alterations under the Clean Air Act.

She did not intend to be in the least cynical when she suggested that, when it was brought to the notice of the domestic consumers the economies that could be made, and how their pockets would benefit, their attention would be arrested and their interest aroused. Indeed, from the many talks she had given to domestic consumers in all parts of London and the Home Counties, it was evident that there was a wide and lively interest in Clean Air and the better utilization of fuel, which showed itself in many pointed questions and much discussion.

It was, however, necessary to use the most direct methods and to state clearly the sums that could be saved. Usually they amounted to between 2s. 11d. and 3s. 7d. per week in a small household, according to the type of fuel used and the length of time the appliance was operated. In addition, of course, there were the further savings arising from less dirt with consequent lower laundry and general maintenance costs, and most important of all, improved health.

Finally, Miss Boyd suggested that it should be possible for local authorities, suppliers of appliances and of fuels, to get together and stage " live " demonstrations—for instance, in a shop in the main shopping centre, where the housewife could see for herself examples of appliances under fire and be informed of the running costs with different kinds of fuel and the economies effected in plain shillings and pence.

Such practical education of public opinion would go a long way to ensure co-operation in administering the Clean Air Act in the domestic field.

Alderman Dr. J. Robinson (Stretford) said that his Borough Council had protested for many years against the great and increasing amount of sulphur used in chemical manufacture in their industrial area, Trafford Park. A field near one of their main roads was covered with sulphur of which two per cent. was allowed to be emitted into an atmosphere already so polluted as to be almost the worst in Great Britain. As two per cent. of an " unlimited quantity " is itself an unlimited quantity, they protested that no area should be expected to suffer so grievous an infliction. They were asking the Association of Municipal Corporations to make representations to the Government, asking for limitation of the total amount of sulphur used in manufacturing processes in any locality. Until this was achieved, there was no hope of getting effective control of atmospheric pollution.

E. G. Thomas (C.P.H.I., Penge U.D.C.) referring to the area reports, stated that quite a number of these reported the establishment of smoke control areas, or proposals to establish such areas at sites being developed or scheduled for future development.

He was concerned with a built-up area comprising cottage and tenement properties. Local Authorities anxious to secure unpolluted air, had to take into account the financial burden connected with smoke control areas. The position was different in such circumstances to that of development areas.

He therefore wished to inquire whether the platform could provide conference with the average cost per house for carrying out the necessary conversions in built-up areas containing multi-type properties.

Referring to enforcement, he made a plea for a suitable scientific instrument to provide more reliable evidence to courts than oral evidence of an observation, subject to atmospheric influence and dependent upon human vision.

Dr. J. S. Robertson (M.O.H., Glanford Brigg R.D.) said he was concerned with the effects of pollution upon health. Present evidence suggested that the oxides of sulphur might be responsible for the acute effects of heavy pollution. He understood that coke might contain as great, or greater, proportions of sulphur than coal, and the desirability of changing to smokeless fuels was therefore debatable. It was probable that the formation of smokeless zones would prove advantageous, but solely because the appliances used had a higher efficiency than the old open fire. If open fires with an efficiency of 15 per cent. were replaced by modern appliances with an efficiency of 30 to 60 per cent., less fuel would be burnt in maintaining comfortable conditions. Sulphur pollution should therefore be greatly reduced, and this advantage accrued irrespective of the fuel used. Could not the snags due to concessionary coal be overcome by insisting upon efficient appliances, but permitting coal to be burnt in them?

Councillor H. Rainger (Fulham) said that, judged by the number of chimneys made smokeless, reports from the Divisions were rather disappointing. Much of the action so far taken or proposed related to city centres, where the number of smoke sources was relatively small, and to newly developed and undeveloped land where the object was prevention rather than cure. Prevention was an excellent thing, but only a minute proportion of the millions of smoking chimneys had been cured.

Conference had heard much about the problems to be met in establishing smoke control areas. Delegates might find this emphasis on difficulties discouraging. In Fulham's experience, difficulties proved much less formidable in practice than in theory.

In his Borough an order had become operative which affected nearly 4,000 premises, most of them Victorian houses needing new appliances or adaptations. Another 6,000 similar properties would be dealt with soon. Fulham had a ten-year programme for making the whole Borough smokeless, and progress so far justified the hope that the work would be finished in a shorter period than that.

He was proud of the work that his Council had done, and of its determination to banish smoke and soot from Fulham. He hoped that other delegates with achievements to report, and encouragement to give, would hearten Conference by coming to the rostrum.

Councillor William Smith (Chairman of Health, Padiham U.D.C. and Vice-Chairman, No. 6 Division Health, Lancashire C.C.) gave his own personal domestic fuel experience. Beginning with the composition of his all-electric terrace-type house, which comprised two bedrooms, dining and drawing room and kitchen. The loading conditions for each room were: kitchen—cooker, washer (unheated), control for 3 kW immersion heater; dining room—2 kW Magicoal radiator and 2 kW convector; drawing room—2 kW Magicoal radiator; bedrooms—2 kW radiator in one and 1 kW in the other.

Miscellaneous items such as vacuum, iron and hair dryer were in use. The speaker then moved to the financial angle, giving figures (1956) previously taken prior to conversion. They were 7s. 3d. for coal and 8s. 0d. for electricity, thus giving a weekly figure of 15s. 3d., or an annual total of £39 13s.

He continued then by reading to the Conference his quarterly accounts for the full twelve months which were as follows:

£10 1s. 11d.—May
£6 16s. 1d.—August
£7 19s. 0d.—November
£15 5s. 0d.—February (which covered a three-week period of sickness with 1 kW radiator being used for 24 hours per day).

This gave a total of £40 2s. 0d.

Councillor Smith concluded by stating that they had no smoke, no fumes, cleaner curtains and decorations, and heating of the rooms being at required temperature, for the small difference in cost. He stated that, in his opinion, for people dwelling in hilly country, or in any dwelling with downdraught trouble causing smoking chimneys electricity was the only fuel to give efficient and satisfactory conditions.

J. S. Riley Jnr. (Lancashire Federation of Coal Merchants) said he was also speaking on behalf of the National Federation of Coal Merchants of Great Britain, and that the Federation was wholeheartedly behind the efforts being made by the Society on behalf of public health, and that the coal merchants throughout the country would co-operate towards that end; but they were somewhat concerned at the speed with which Smoke Control Areas were being brought about.

The reason for their concern was the

acute shortage of popular solid smokeless fuels, such as Anthracite Stove Nuts, Group 2—3½ months delay; Groups 1 and 3 Anthracite Stove Nuts—approximately 8–11 weeks delay; Coalite—approximately 4 weeks delay.

Mr. Riley also pointed out that a recent survey conducted by the Women's Advisory Council on Solid Fuel showed beyond doubt that coke used in the open grate was not popular, and if local Councils were persuaded by over enthusiastic officials, this could lead to great embarrassment of local Councils.

He concluded by urging that the introduction of smokeless zones be kept in step with the production of solid smokeless fuels, especially the reactive type.

L. Mair (C.P.H.I., Newcastle upon Tyne) referred to the steady progress being made in the North West, Yorkshire, Midlands and South East Divisions, but deplored the sorry picture portrayed in the report relating to the North East Division. In discussing the causes of apathy and inactivity in that Division, of which his own Authority was a constituent authority, Mr. Mair disagreed with the suggestions in the report that the education of school leavers and the holding of additional meetings of the North East Divisional Council were "great needs to be settled before progress can be seen." He suggested that progress would more effectively be established if educational activity was directed at certain North East local authorities rather than at teenage school leavers.

Alderman Mrs. A. L. Barker (Stoke-on-Trent) drew attention to the number of District reports containing references to concessionary coal. In the mining districts of the country that constituted a major problem for the Local Authorities wishing to designate smoke control areas.

In Stoke-on-Trent, 20,000 people were receiving concessionary coal, for which they were paying in the region of 15s. 10d. per ton. In four small areas, for which application was being made to the Minister to designate as controlled areas, 20 per cent. of the houses were occupied by miners. She asked the Conference if they thought that miners were going to be willing to give up coal at 15s. 10d. per ton and buy smokeless fuel, paying in the region of £7 to £9 per ton.

She appealed for some action to be taken between the nationalized industries for arrangements to be made for the equivalent amount of smokeless fuel, in one form or another, to be made available to miners. This was a national problem, and she felt that the Conference should do all in its power to bring home to the Minister the necessity to settle this problem at national level.

J. Innes, replying to the discussion, said that the answer to Councillor Dr. Ashworth's question, the introduction of gas to premises in Smoke Control Areas did rank for grant. In reply to Dr. Robertson, Mr. Innes said that modern appliances of improved efficiency did not, in his experience, burn less fuel, but they did make greater effective heat available in the premises. He feared that sulphur pollution would not be reduced by burning solid smokeless fuel and the comments on concessionary coal and efficient appliances did not make sense

Mr. Riley had claimed that the National Federation of Coal Merchants were behind the Society's efforts, but this was not evident north of the Border, and the reverse was the case in many districts where demands were made by the public for approved fuels. Some instructions to members of the Federation on the subject would not be amiss.

Alfred Wade, in reply to the question by E. G. Thomas said that estimates of the cost of converting appliances for smokeless operation had been given by several Authorities. The Beaver Committee, in their report, stated that the total cost should not exceed £10 per house, and a similar figure had been estimated by the City of Birmingham in respect of a large number of conversions. Much would depend, however, on the types of houses dealt with. In the central area of the City of Nottingham where there were large three-storied houses, some of which were let to numerous tenants, the average cost would undoubtedly be higher.

Geo. W. Tate, replying, said that Mr. Mair in his contribution had rightly deplored apathy and inactivity in the North East Division, but had ignored what could be a major factor in this concessionary coal problem. He had also disagreed with suggestions in the report and suggested that progress would be more effective if the educational activity was directed at certain North East local authorities. Mr. Tate said he would commend the re-reading of the whole paragraph, and not a portion taken from its context, when it would be found that "school leavers as well as adults" were suggested as targets for education, and this surely included members of local authorities.

A further word on Miners' concessionary coal would appear to be necessary to point the proper approach to the problem. In the report he had said: " Two thirds of the authorities are faced with the problems of Miners' concessionary coal, the adjustment of which they rightly claim is outside their jurisdiction. . ."

What he failed to appreciate when the report was prepared was that concessionary coal, and what it meant, was not fully understood by those away from a mining area, and it was because of that that he was prompted to attempt to clarify the position.

Prior to nationalization the wages and conditions of mineworkers were negotiated at Area (or County) level. Now, the wages of all workers except those of Piece workers were fixed at national level, but the conditions and concessions were still dealt with at Area or County level.

Northumberland and Durham County were the only two Areas in the country which enjoyed " free house and coal." (Reference to the Wages Structure pre-1947 would show how much these were assessed at in all wage negotiations.) All other Areas had house and coal at agreed rents and prices, and these rates varied from Area to Area.

Thus it could be seen to be a matter of wage negotiation, not with any Minister (at least at this stage), but one between the National Coal Board and the National Union of Mineworkers—at Area or County Level.

With both sides ready and willing to reach a fair and satisfactory conclusion, continued Mr. Tate, a major stumbling block to clean air in mining areas would be removed. Wages and conditions were most certainly a matter for master and men to deal with, but let the conference not forget that atmospheric pollution was a matter to be dealt with by all who are afflicted with it.

M. F. Scott (a member of the platform Panel, representing the Wales Gas Board), replied as follows:

He was delighted to hear Councillor Smith speak on the use of electricity in place of coal and produce accounts which showed that for a little additional cost he was able to replace coal altogether. They in the Gas Industry were not surprised at this statement as they now had ample evidence that they could completely replace solid fuel by gas for all domestic heat services and actually show a saving in annual running costs.

Practical district tests had revealed that, using gas, savings of up to 8 per cent were obtainable, together with a much superior heat service and all the other advantages such as cleanliness and ease of control, etc.

All Area Boards now had suitable gas tariffs designed for the specific purpose of making it financially attractive to the consumer to replace coal fires with gas convector fires in the living room and to fit a suitable water heater for all requirements.

Scientific and Technical Section

AIR POLLUTION IN LONDON AND ITS SMOKELESS ZONES

by

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1. Introduction

A PLAN for a co-ordinated survey of air pollution in London was recently prepared by the Fuel Research Station for the Metropolitan Boroughs Standing Joint Committee. This plan resulted in the installation of additional measuring instruments to bring the total to more than 300 at selected sites in the central 150 square miles of the London area by the beginning of 1957. The present paper is a tentative assessment of the first year's results of that survey.

Although the survey was designed primarily to provide information for local use on the distribution of various pollutants, it clearly has a wider significance. Experience in sampling large areas is meagre, consequently the distribution of instruments recommended in the London plan was to some extent experimental. The results should therefore be some guide to other authorities wishing to undertake detailed surveys, for example to identify those areas where measures of abatement are most required and to record the progress made towards clean air.

The London survey also has a special interest because of the smokeless zone in the City of London. This country's hopes of clean air depend to a large extent on the idea of the spreading smokeless zone (or smoke control area) first suggested more than 20 years ago by the late Charles Gandy, the then Chairman of this Society. There can be no doubt that if this idea is carried into effect it must ultimately be successful. But what of the intermediate stages? It has often been said that air pollution does not stop at local boundaries and that the air of a smokeless zone surrounded by smoky neighbours would be swamped by their emissions so that there would be no appreciable local benefit. Scientific evidence on this point is both meagre and conflicting. On the basis of some calculations referred to in the Leicester report[1] it was calculated that a surrounded smokeless zone one square mile in area could expect to enjoy a reduction in smoke concentration at its centre amounting to about 58 per cent. However, some short period tests in Hyde Park, which is of about one square mile in area, indicated a maximum improvement of only 27 per cent. and from this latter result it was concluded that obvious improvements in the atmosphere could only be expected in smokeless zones considerably larger than one square mile.[2]

The results described in the present paper indicate the probability of a 40 per cent. reduction in average smoke pollution over much of the City's smokeless zone which more nearly agrees with the calculated figure of a maximum at the centre of 58 per cent. This result if confirmed, should provide some encouragement to authorities who may be considering embarking on smoke control areas.

2. Pollution Measurements

The pollutants being studied in this survey are deposited matter, sulphur dioxide and smoke. The methods of measurement have been fully described[3] and need only be outlined here.

Deposited matter is collected in a British Standard Deposit Gauge for a month and the solid and aqueous deposits then separated by filtration and analysed. The results are normally expressed either in grammes per 100 square metres per month (gm./100 m^2/mth.) or in tons per square mile per month (tons/mi^2/mth.).

Atmospheric sulphur, mainly sulphur dioxide, is measured empirically by exposing a standard lead-peroxide surface to the atmosphere for a month and then determining analytically the amount of sulphur absorbed. The results are expressed by the analyst in the recognized empirical units. Sulphur dioxide is also measured daily by the " volumetric " method in which a measured volume of air is drawn through hydrogen peroxide solution and the amount of acid thus collected is determined by titration with alkali. The results by this method are generally expressed as parts of sulphur dioxide by volume per 100 million parts of air (p.p.h.m.).

The correlation between the two methods is only approximate because, although sulphur dioxide is the major pollutant determining the result in each case, the lead peroxide method is also affected by some other sulphur compounds and the volumetric method includes other acids as the equivalent of sulphur dioxide.

Smoke concentrations are determined by drawing a measured sample of air through a filter paper, usually for 24 hours, and then measuring the intensity of the stain produced. The measurement is made either by a visual comparison with a set of standards or preferably photoelectrically and the weight of smoke calculated on the basis of a previous calibration. The results are expressed in milligrams of smoke per 100 cubic metres of air (mg./100m^3). In general the smoke and volumetric sulphur dioxide determinations are combined in the same apparatus.

To avoid personal errors which might have been incurred in the smoke determination if the stains were assessed by the visual method, all the results used in this paper were obtained by photoelectric measurements made at the Fuel Research Station.

Fig. 1 shows the area covered by the survey, the locations of the smokeless zones (including the larger open spaces) and of some of the boroughs. A relatively small smokeless zone in Tottenham is not shown.

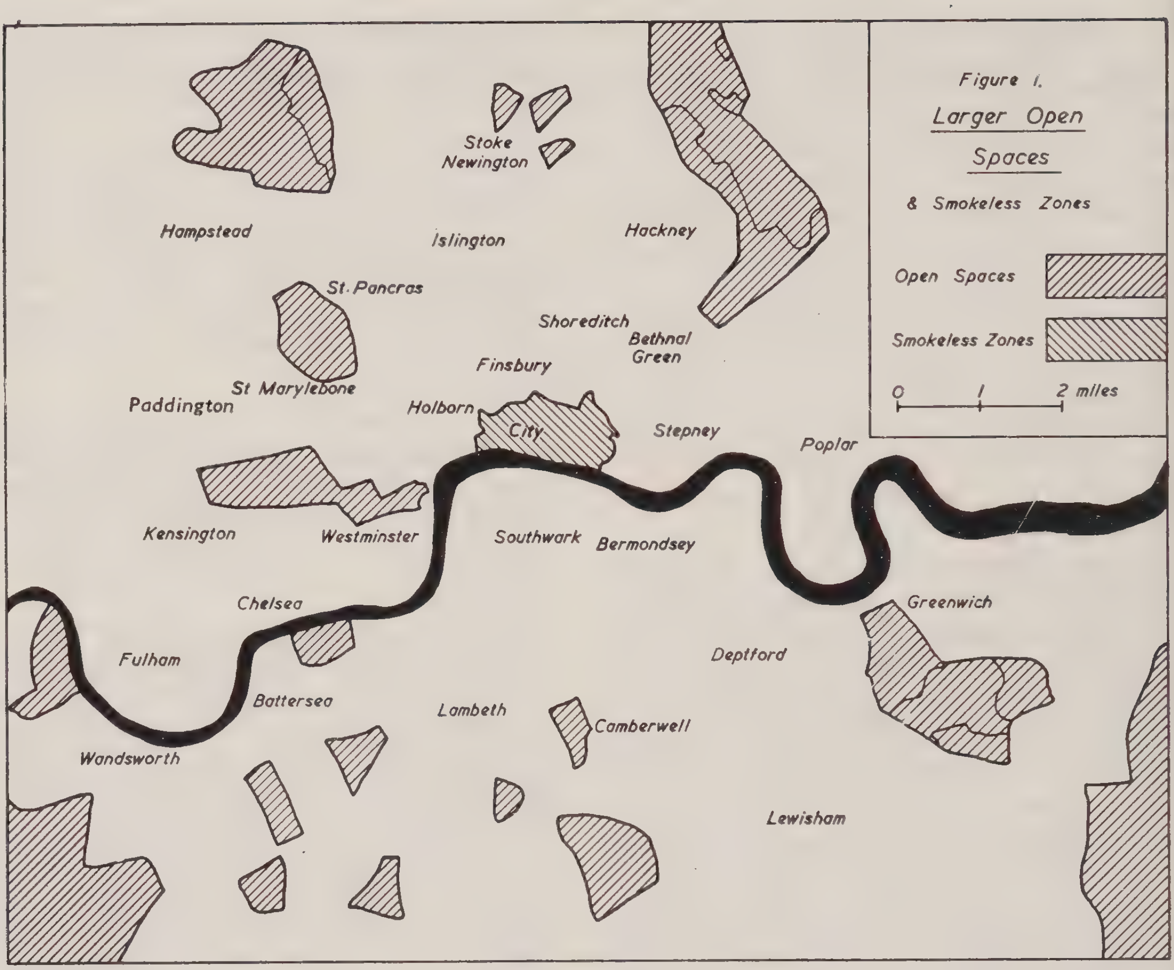
The locations of the various measuring instruments are shown in Figs. 2 to 7; their numbers, including a few just outside the area but near enough to contribute, comprised 67 deposit gauges, 68 smoke filters, 68 volumetric and 106 lead peroxide instruments for sulphur dioxide. Thus over the whole area the density of instrumentation was equivalent to one instrument of each type to every 1½ to 2¼ square miles; over parts of the central area, including the city smokeless zone, there were several instruments of each kind to each square mile.

3. Results

In Figs. 2 to 7 the results are shown as " contours " which delineate areas of approximately equal pollution. A few results (about 2 per cent.) had to be ignored because they recorded results too high to fit into the general pattern. Minor irregularities in the contours have been smoothed without changing the main characteristics and broken lines have been used in those areas where the greatest uncertainty exists.

The pattern of deposits. Fig. 2, which relates to the total insoluble deposits of grit and dust, indicates a belt of relatively high pollution in the riverside areas, particularly in east London. There is no evidence of lower rates of deposition in the City's smokeless zone.

Owing to the tendency for dust to



settle near its source it was not expected that the results would conform to so simple and instructive a pattern as that shown in Fig. 2. Satisfactorily, the criteria for the selection of test-sites appear to have excluded sites where the background pollution pattern is modified by very local sources of dust.

The total water-soluble deposits did not conform to any simple pattern although there was a tendency for higher values to occur in the central London area.

The pattern of sulphur dioxide. Fig. 3 shows the results by the lead-peroxide method over an area which stretches further down the Thames estuary than that of the other surveys. The area of maximum pollution is again along the river valley; in this instance it is mainly north of the river stretching from Paddington and Westminster to Dagenham. The general pattern is very similar to that observed in a survey using fewer instruments in 1951[4]; in both there is the break in the pattern in the Poplar area which, it is suggested, may be due to the below-average population density in that borough and possibly also the adjacent open spaces of the Lea Valley and Greenwich. The reproducibility of the pattern over a period of years would seem to indicate that it relates to permanent characteristics of the locality.

The volumetric sulphur survey illustrated in Fig. 4 does not include the heavily polluted zone to the east of Poplar because no instruments were there. Both methods of sulphur measurement show the heavily polluted zone between Westminster and Stepney although the patterns are not identical particularly in the City. As previously explained exact correlation of the two methods is unobtainable because of the secondary effects of other forms of sulphur than sulphur dioxide and of other acids.

The pattern of smoke. The average distribution of smoke shown in Fig. 5 is characterized mainly by (*a*) a central

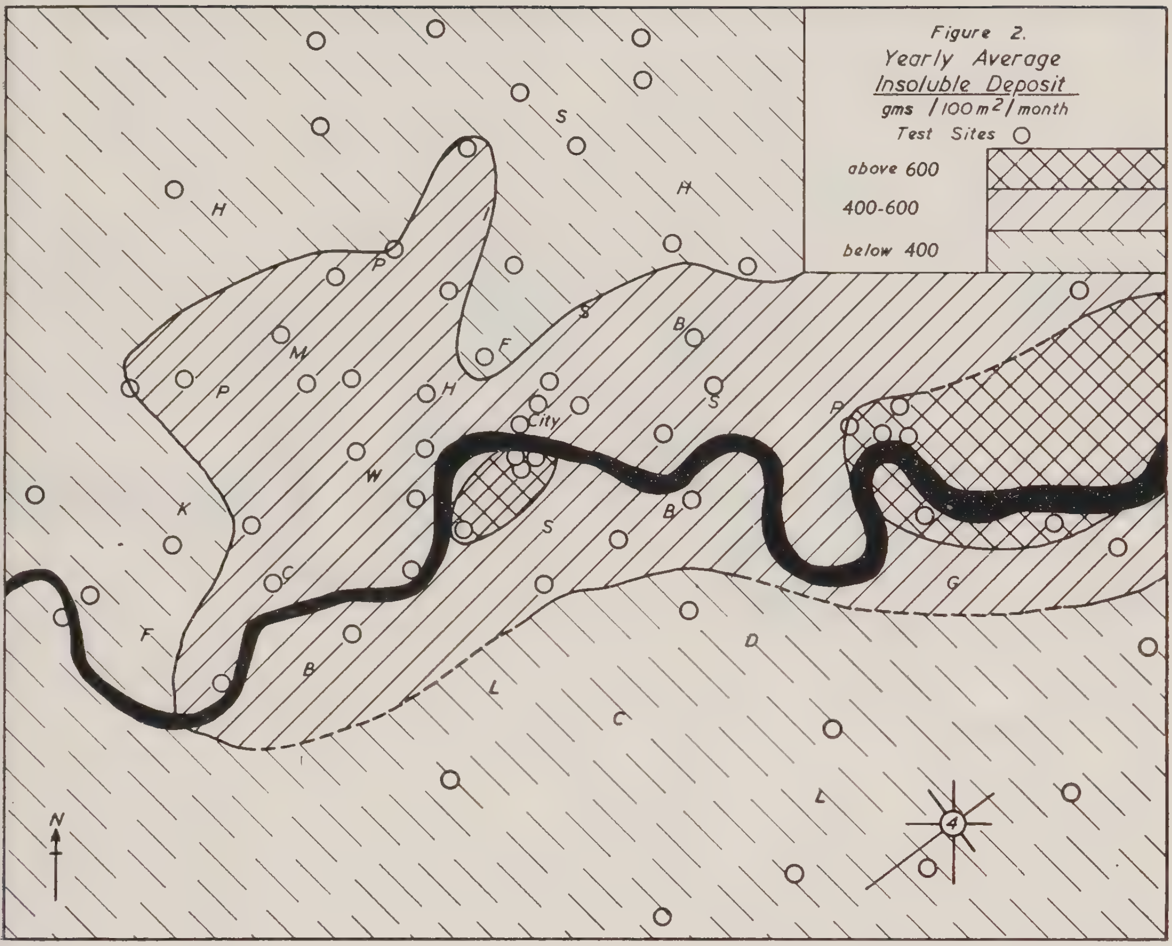


Figure 2. Yearly Average Insoluble Deposit

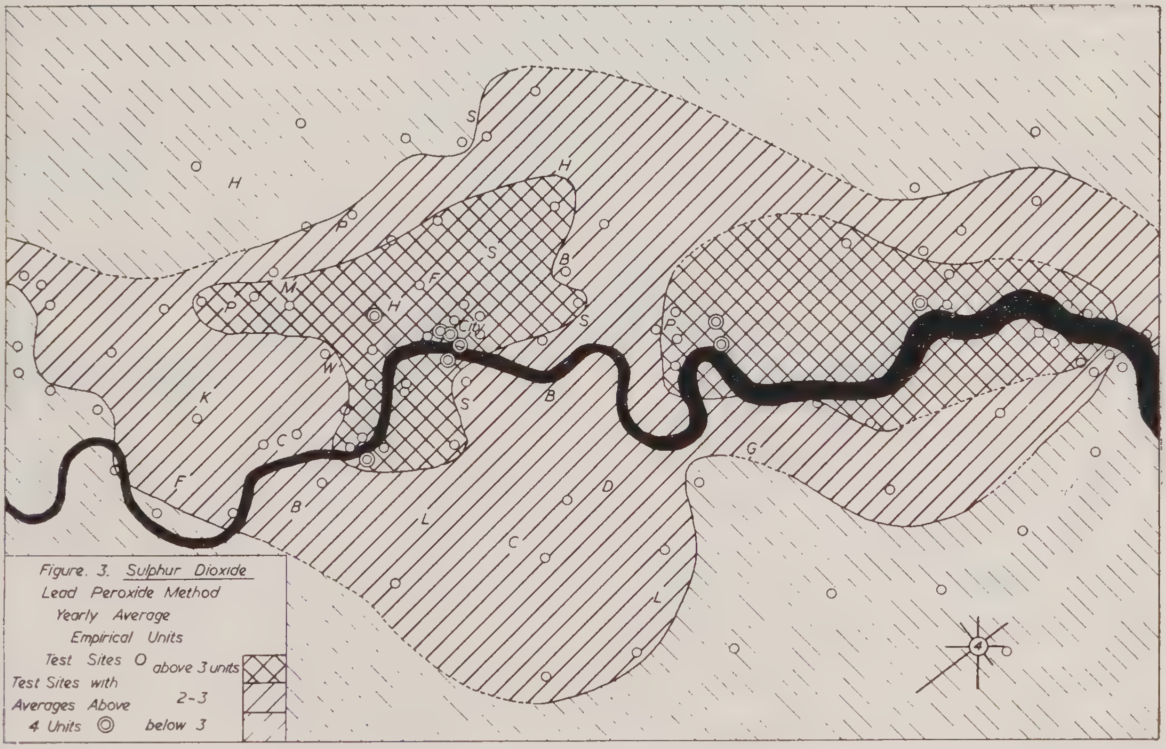


Figure. 3. Sulphur Dioxide Lead Peroxide Method Yearly Average Empirical Units

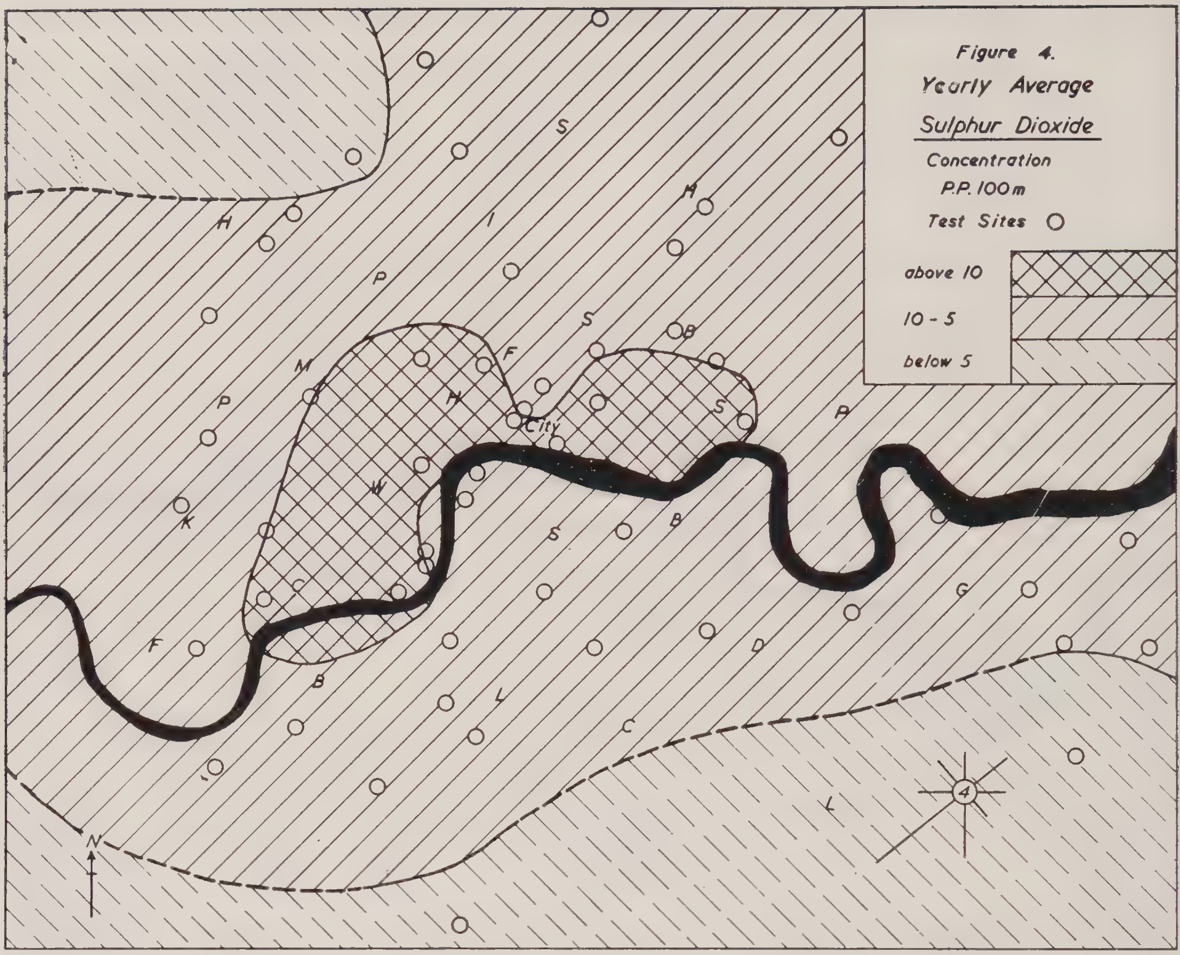


Figure 4. Yearly Average Sulphur Dioxide Concentration P.P. 100m

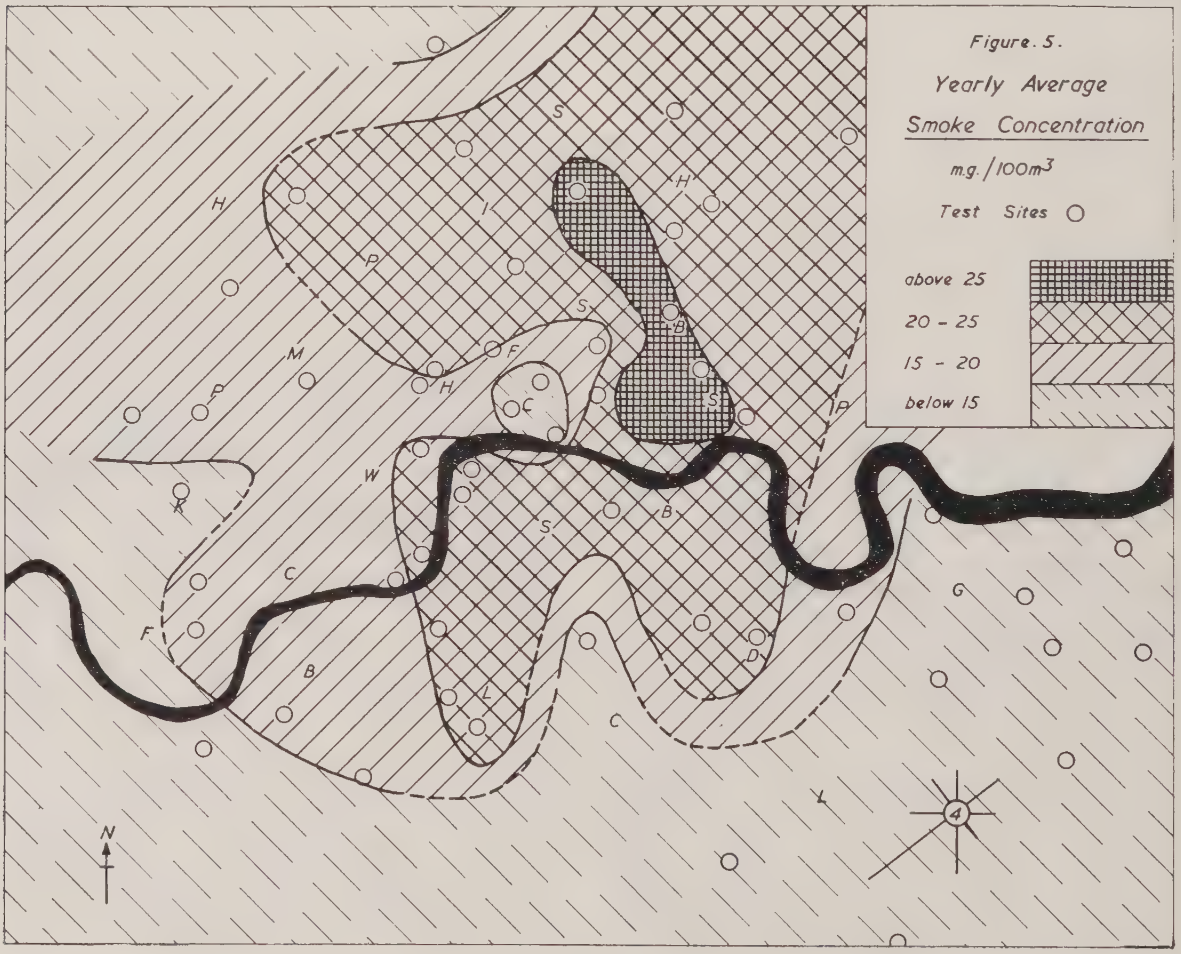


Figure. 5. Yearly Average Smoke Concentration m.g./100m³

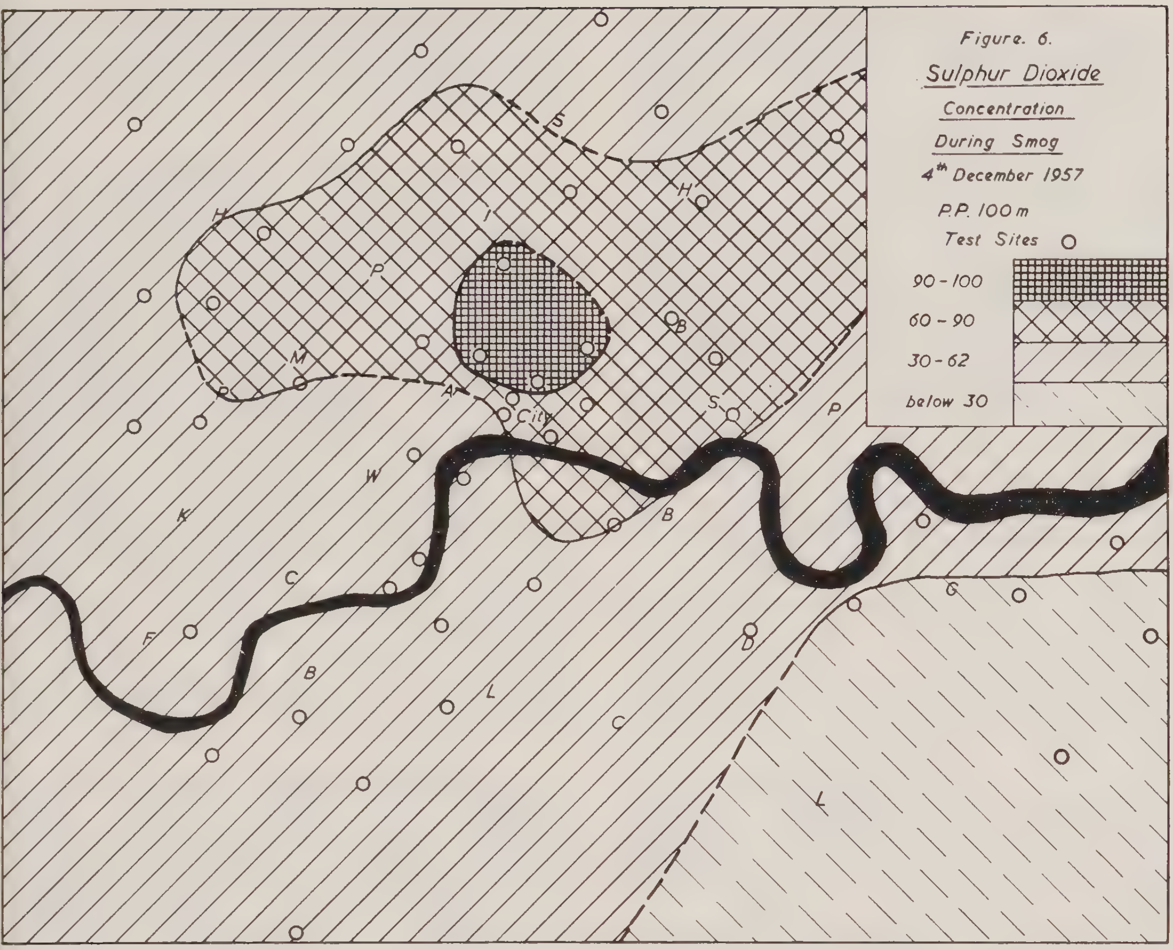


Figure. 6.

Sulphur Dioxide Concentration During Smog

4th December 1957

P.P. 100 m

Test Sites ○

90 - 100 ▦

60 - 90 ▩

30 - 62 ▨

below 30 ▧

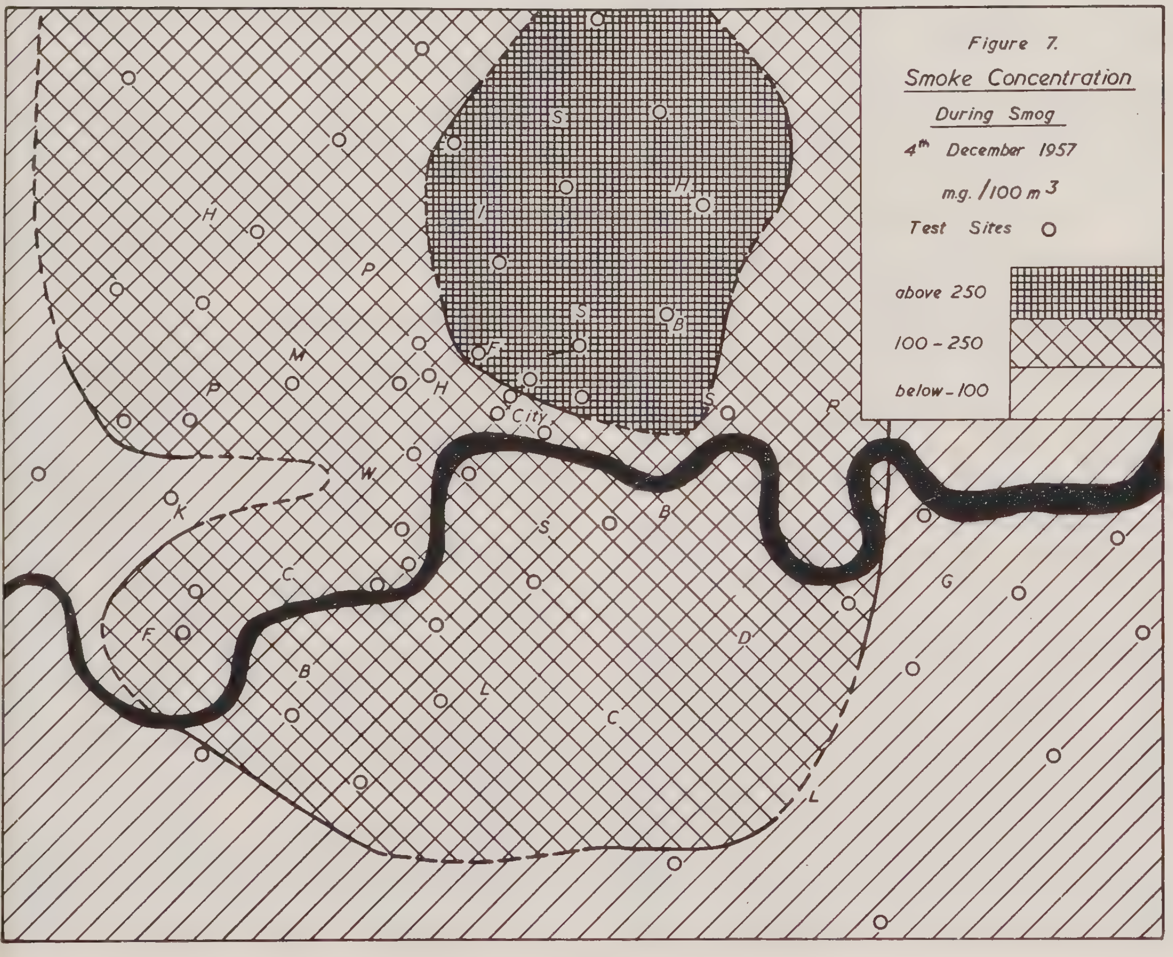


Figure 7.

Smoke Concentration During Smog

4th December 1957

m.g. /100 m^3

Test Sites ○

above 250 ▦

100 - 250 ▩

below - 100 ▨

area of maximum pollution (more than 25 mg./100 m^3) to the north and east of the City of London, (*b*) an area covering about one half of the City of London's Smokeless Zone in which the average smoke concentration is less than 15 mg./100 m^3, i.e. about equivalent to that of most of the suburban areas shown and approximately 40 per cent. less than that in the adjacent boroughs, (*c*) a general decrease with increasing distance from the centre, equivalent to 50 per cent. in a distance of about five miles.

The difference between the City and the surrounding areas persists in both summer and winter seasons. A tentative comparison of the patterns when winds are north-easterly with that for average (predominantly south-westerly) winds indicated no appreciable shift in the position of the cleaner City zone or other features of the pattern. The absence of evidence for low-level streaming of smoke with the wind was not expected and needs further examination; clearly it is important to know how pollutants from one area affect others and under what conditions.

The pattern of pollution during smog. For a few days in early December 1957 smog covered much of the London area causing about 300 extra deaths from ill-health in the County of London[5] or about 1,000 in the whole of Greater London.[6] It was therefore an incident of major severity.

In Figs. 6 and 7 are shown the average concentrations of sulphur dioxide and smoke on the 4th December, which was the day when the highest values were observed at most sites. It will be noted that the patterns are roughly concentric with maxima in the central London area of about ten times the yearly average. More detailed information is obtainable by operating the standard instruments for periods of a few hours and many local authorities have made such measurements during smog. Where detailed mortality and morbidity data are available measurements of pollution by standard instruments have been used in statistical studies of its effects on health both during smog and at other times.[7]

4. Summary and Conclusions

This paper is a first attempt to survey air pollution over a large area on the basis of one year's results. A total of 300 measuring instruments were located at carefully selected "average" sites over 150 square miles of the London area. Relatively simple and rational patterns of pollution have been obtained for insoluble deposits (dust), sulphur dioxide and smoke; for total soluble deposits the pattern was less distinct. It is suggested that surveys on these lines, in greater or less detail, would be of assistance to authorities implementing the Clean Air Act.

An attempt has been made to estimate the reduction of smoke concentration in the City of London's Smokeless Zone. It is not possible at this stage to make a firm assessment but there are indications that the average concentration over much of the smokeless zone is about 40 per cent. below that of the adjacent boroughs. Measurements of dust deposition and sulphur dioxide showed no reduction in the City but sulphur dioxide and smoke appeared to be reduced over some large open spaces.

5. Acknowledgments

The authors wish to acknowledge the co-operation of the various local authorities whose instruments provided the data for this paper. They also thank those members of the Fuel Research Station staff who have assisted, particularly Mr. J. R. Goss who was responsible for siting most of the instruments with which the measurements were made, and Miss M. Wells and Mr. P. Daniel who made many thousands of photoelectric assessments of smoke stains.

The investigation described was part of the research programme of the Fuel Research Station and is published by permission of the Director of Fuel

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AIR POLLUTION AND RESPIRATORY DISEASE

by

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"THE public," said Dr. William Farr, the first medical statistician to the General Register Office, " do not seek the shield of medical art against disease, nor call the surgeon, till the arrows of death already rankle in the veins." It would be easy to dismiss this warning as colourful Victorian rhetoric; but it is fair to say that until the great smog of London in 1952, the public and the medical profession were strangely complacent about the problem of chronic respiratory disease in this country. Chronic bronchitis and emphysema is a disease condition for which no dramatically effective treatment has yet been found to halt and reverse its insidious course. As Dr. J. G. Scadding, Dean of the Institute for Diseases of the Chest in London, remarked in a review of a book on chronic bronchitis published in 1952, it is " a difficult, unpromising and neglected subject." In that year, the same disease was the registered cause of death of one in 13 of all deaths among men between the ages of 45 and 64; yet less than half a dozen articles on it appeared in the medical weeklies in the year of the London smog. Meanwhile, the gross differences in bronchitis between the sexes, the social classes, and town and country or between this country and others stimulated more comment than research.

The Problem in Perspective

Tempting as it may be to fulminate against our own blindness, the inherent difficulties should be clearly recognized. Until 1952 the acute effects of air pollution on the respiratory cripple had never been so widely demonstrated to public and profession alike. Again, although air pollution is a likely cause for the difference in bronchitic mortality between town and country, there is no lack of sensible alternative explanations. The urban male in particular is exposed to more frequent risk of infection from the many human contacts of life in a crowded city. Overcrowding within the home may increase the risk still further. Work in urban factories which may expose them to the dust, fumes and exertions of the heavier jobs in industry might explain part of the excessive death rate in the labouring classes. The social gradient in mortality which exists for women as well as men may also reflect differences in standards of habitual diet or care during illness. Equally, the male urban excess could be due to their higher consumption of cigarettes.

The problem is, then, to disentangle the many threads which make up the pattern of chronic respiratory disease so that their separate individual importance in causation can be assessed and priorities in preventive action decided. Like all facile solutions, this is easier said than done. The same man can be at the same time a heavy smoking, hard drinking, underfed labourer working in a dust-ridden industry and living in a crowded flat in a smoky and congested urban environment. On clinical evidence alone, it requires a judgement of Solomon to apportion responsibility for his chronic bronchitis between the various factors which may be implicated. It is in such circumstances that the epidemiological approach—or the study of the distribution and behaviour of disease in differing conditions of life in a community—may further our understanding of its origin. My purpose is to recount the aims, methods and some of the results of a few current British studies of this kind on the relation of air pollution to respiratory disease.

The Geography of Bronchitis and other Respiratory Disease in Civil Servants

The most striking feature of the death rates from bronchitis is the concentration in urban areas and among semi-skilled and unskilled workers. We can try to isolate the effect of geographical differences from occupational exposure by comparing men who, although they all work at the same job, live in different parts of the country. Through the courtesy of the Treasury, the Post Office and the Treasury Medical Service, Dr. A. S. Fairbairn and I[1] were able to carry out a survey of the rates of sickness and premature death or retirement for specified causes among civil servants working in different parts of the United Kingdom. These men and women have uniform rates of pay and type of work so that social, economic and occupational circumstances are likely to be much the same wherever they work. On the other hand, postmen in town and country, for example, have to do that same job but in very different local conditions. Clerical officers, although they share with postmen the general environment of the town in which they both work, are not exposed to the outside air during their working hours. If, then, we compare the frequency of premature death or retirement because of bronchitis in postmen working in urban or rural parts of the country, we can be reasonably sure that any differences observed are not due to differences in pay or job. Because of the differing physical demands of their occupations postmen will always have higher rates of unfitness for work than clerical officers working in the same area. Generally speaking, however, if local conditions exert no influence on the frequency of absence from work because of bronchitis or any other cause, the ratio of sickness absence among postmen to that among clerks should be much about the same all over the country. Adverse outside conditions will have a disproportionate effect on the sickness experience of the postmen.

As it happened, some pre-war observations on the frequency of thick fog, made by Mr. Durst of the Meteorological Office provided a ready made index of presumptive air pollution at many points all over the country; for a comparison of the frequency of visibility being restricted to less than 1,100 yards with other measures of local air pollution such as SO_2 or smoke concentrations showed that they were all highly correlated. The country could thus be divided up into 37 reasonably homogeneous urban or rural areas. Those areas were ranked in order of their

TABLE 1

Local Fog Frequency and Bronchitis and Pneumonia Sickness Absence Rates in Civil Servants*

Occupation	I	II	III	IV
(1) Postmen	40	53	115	122
(2) Indoor male office staff	32	41	47	39
(3) Ratio $\frac{(1)}{(2)}$	1·25	1·29	2·45	3·13

* Age standardized Attack Rates per 1,000 man years.

local fog levels and divided first into four major groupings (I to IV) according to the frequency there of thick and presumably polluted fog.

Table I shows quite clearly that postmen have more frequent absences because of bronchitis and pneumonia than the corresponding indoor clerical workers in the areas of the country (groups III and IV) where thick fog was most frequent. The gap for other kinds of diseases was not nearly so marked and it thus seems that the effect of working out of doors in these fog-ridden districts was to increase quite markedly and specifically the frequency of attacks of disabling bronchitis and other serious respiratory disease.

By going back over the sickness records of postmen who had died or been retired prematurely because of chronic respiratory disease, it was possible[2] to trace the natural history of the illness as it evolved during working life. Many of the men had histories of repeated attacks of respiratory infections and asthma early in adult life so that there is certainly some evidence of personal predisposition. Others had histories of repeated attacks of respiratory infections which dated from either pleurisy or pneumonia. Of perhaps the greatest significance from the point of view of air pollution was the suggestion that not only did postmen in the foggier districts more frequently develop severely disabling chronic bronchitis but the character of that illness was different. After the age of 25, the frequency of attacks increased in all areas, but relatively much more in the polluted districts. There were more serious respiratory complications like pleurisy and pneumonia; and, particularly among men in the critical age groups 45-54, more frequent absences due to disorders of the circulation with all the worsening of the outlook for survival which such complications entail. Indeed, once the disease has begun, the length of survival is appreciably less in the worst affected districts where 11 per cent. of the men die during their last period of sick leave and 44 per cent. of those who survive until retirement are dead within six years thereafter.

Air Pollution and other Local Factors in Respiratory Disease

Bronchitis is not, of course, the only respiratory disease which may be associated with air pollution; and air pollution is certainly not its only cause. By studying the relationship of various types of respiratory disease to different conditions of local environment, it may be possible to discover patterns of disease behaviour which may suggest cause and effect. In the Civil Service study, for example, the 37 areas into which the United Kingdom was divided were also classified according to population density and the degree of local domestic overcrowding. The rates of disability or death from bronchitis, lung cancer, pulmonary tuberculosis and influenza among either postmen or other males between 45 and 64 in the same local populations were then correlated with these indices of local conditions as well as the index of air pollution already used. Briefly, this analysis showed that there was a grading in the relationship of either morbidity or mortality from these diseases to local environment. At one end of the scale the bronchitis rates were most closely related to local levels of air pollution and much less closely to local population density or domestic overcrowding. At the other end stands influenzal morbidity which was most closely related to domestic overcrowding and not at all to local air pollution levels. Between these extremes, lung cancer showed only a small correlation with pollution but quite a close one with population density. Pulmonary tuberculosis was similar but with a more definite association with overcrowding. A simple interpretation of these relationships might be that while bronchitis mortality is most affected by urban air pollution, the congestion of city lives and homes has its greatest effect on infectious diseases like influenza and tuberculosis. The lung cancer correlations can be less readily explained; but it is possible that population density or urbanization is as much an index of the urban habit of cigarette smoking as of the frequency of human infective contacts. The fact that more densely populated areas have higher lung cancer death rates may thus be a reflection of more cigarette smoking rather than of air pollution due to a concentration of chimneys or of multiple infections.

Statistics of Respiratory Disease in Town and Country

Crude though these methods are, there is a consistency in the results which lends caution to any naïve assumptions that urban:rural differences in lung cancer death rates can be entirely explained by differing levels of local air pollution. Mr. Waller of the Medical Research Council's Group for Research on Atmospheric Pollution[3] has recently reported on some other vital statistical evidence which points in the same direction. It is true that there is a consistent rise at all ages in the death rates from cancer of the lung between rural districts, urban districts and county boroughs with maximum rates in London. Since the beginning of the century, the peak in this death rate has shifted back from about 70 to between 60 and 64 and then returned to the older age period. This sort of movement would be consistent with the younger people in the early 1900's beginning to smoke cigarettes while the older generation carried on with their pipes. Then as the generations born after 1880 grow up, the peak, now at an even higher level, is moving back to later life. Waller could find no change in the volume or nature of air pollution which would fit in with this rising peak in lung cancer. He also found that this same movement, suggestive of the influence of a new factor, appeared first in London and then successively in county boroughs, urban and finally rural districts. From this he concluded that much of the urban:rural differences in the past have been due to the later spread of the cigarette smoking habit from the metropolis out to the country districts. This suggestion would explain why the lung cancer death rate was more closely related to population density, which is a measure of the degree of urbanization and urban habits such as cigarette smoking, than to the index of air pollution.

An excellent example of local initiative in linking air pollution measurement with respiratory disease is given by the work of Mr. H. T. Gore and Mr. C. W. Shaddick of the L.C.C., Public Health Department[4]. They have shown how in the London fog in January 1956, a rise in the level of smoke and sulphur dioxide to above four times the usual winter average caused an immediate rise in mortality, mainly from heart and chest disease, among older people. They also pointed out that the death rate from respiratory diseases, particularly bronchitis, was highest in those districts of London where proportionately more of the population had been born in London. They thought it likely, therefore, that duration of exposure to London's polluted atmosphere had a decisive effect in increasing the risk of death from chest disease.

Field Studies in Bronchitis

Inevitably, these broad surveys give grounds for informed speculation rather than proof. Clues thus uncovered may be followed up by a much more detailed study of smaller groups of the population; and a number of such studies are in hand in this country. At the Medical Research Council's Pneumoconiosis Research Unit, for example, the epidemiology section is engaged in a series of surveys of adults of both sexes living in different parts of the country. Dr. Ian Higgins, of that Unit, has reported[5] a male excess in the prevalence of a symptomatic history suggestive of chronic bronchitis which accords with the higher male death rate from that cause.

More light may be thrown on the relevance of smoking, local air pollution and occupational exposure to the presence of symptoms of serious respiratory disorder by a survey now being conducted by members of the College of General Practitioners. In urban and rural areas all over the country, practitioners have volunteered to interview a randomly selected sample of men and women in their practice lists in order to elicit a history of their respiratory symptoms and disabling illnesses, their smoking habits, residence and occupation. These facts may be useful in deciding whether there is a disparity in the frequency of bronchitic syndromes in town and country practices and in how far any such contrasts can be explained by differing occupational or smoking experience.

A Survey of Cigarette Smoking and Air Pollution in Lung Cancer

A most important report has just been published by the British Empire Cancer Campaign[6] whose Senior Research Fellow, Dr. Percy Stocks, gave much of the initial impetus to the development of studies of environmental factors in cancer causation. He has followed up his own early observations on the association of air pollution and lung cancer in different parts of England and Wales by conducting a special cancer survey in the Liverpool Hospital Region, North Wales and the Isle of Man—an area with a population of some $2\frac{1}{2}$ millions. All cancer deaths in this area over a period of five years were investigated and a comparative study made of the detailed history, e.g. of smoking habits and usual diet, of 16,000 cancer patients and over 20,000 patients suffering from other diseases. Measurements of air pollution were made at points scattered throughout the region. These showed that the smoke and sulphur-dioxide concentration in very small urban areas with rural surroundings is about one-eighth of that in Liverpool; and the levels elsewhere generally increase in step with the degree of urbanization. It was thus possible to compare the death rates from lung cancer in non-smokers and men smoking up to 200 or more cigarettes a week living in different conditions of air pollution. The first stage of this two-way analysis is seen in Table 2. The rates according to smoking habits averaged over all the four areas with different degrees of air pollution, confirm the association between cigarette smoking and lung cancer for the rate among cigarette smokers was four to five times greater than those for non-smokers. The crucial point which Dr. Stocks makes, however, lies in the comparison of lung cancer death rates averaged over all smoking categories for the areas of different pollution. In Liverpool and Merseyside the rates are twice as high as in the less polluted districts. The urban:rural ratio for non-smokers is also about two. Amongst non-smokers who have spent their lives in the country districts, the male and female death rates are practically identical. Of perhaps more general significance, however, is the fact that among those smoking more than 200 cigarettes a week there is little difference between Liverpool and the less polluted areas. In other words, there appears to be a saturation point at which cigarette smoking has precipitated cancer of the lung in all those predisposed to it and the addition of

TABLE 2

Lung Cancer Death Rates in Smokers and Non-Smokers in areas of Differing Air Pollution*

	Maximum Weekly Cigarettes Smoked					*Average*
	0	65	125	175	250	*Rates*
North Wales Seaboard ..	0·22	0·69	1·47	2·32	3·44	1·63
Denbigh S.E. Cheshire ..	0·19	1·00	2·01	1·71	2·79	1·54
Lancashire W. and S.W. ..	0·25	0·98	1·75	1·84	3·64	1·69
Liverpool and Lancs. (Mersey)	0·50	1·68	2·48	3·89	3·27	2·36
Average Rates	0·29	1·09	1·93	2·44	3·29	

* Standardized Death Rates per 1,000 per annum from Dr. Stock's report.

air pollution causes no appreciable increase in the death risk from this cause.

Although these results derive from only one area, the general drift of the accumulating evidence seems to be that the cigarette and air pollution theories of the promotion of lung cancer are not mutually exclusive. Both agents appear to add their quota to the mounting insult to the respiratory system which eventually produces malignant change. But, of the two, cigarette smoking has, in present circumstances in this country, the dominant effect.

Respiratory Infections in Childhood

However precocious the modern child may appear, cigarette smoking is not yet a universal habit in primary schools. The respiratory disease experience of the young rather than the old may thus be more informative about the effects of urban life unalloyed by the complicating influence of smoking habits. Dr. J. A. H. Lee, of the Medical Research Council's Social Medicine Research Unit[7], has made an interesting use of the results of school medical inspections and medical examinations of young men registering for national service in various parts of the country. He confirmed that the frequency of chronic otitis media varied widely with particularly high rates for cities like Glasgow.

Otitis media has a social class and geographical distribution like that of chronic bronchitis. The question therefore arises of the rôle of air pollution not perhaps in initiating minor respiratory disease but in changing the mild ubiquitous infections of youth into more serious and complicated disease of the respiratory tract and the sinuses in nose and ear. Some studies of such infections in school children living in different parts of Sheffield where the pollution levels vary are now being pursued by the Medical Research Council's Group for Air Pollution Research there.

Conclusion

Research in community medicine demands the help and willing cooperation of the public and the public's government both central and local. Thus far, such help has brought us real, if slow, progress in our understanding of the agents in the air we breathe which threaten the public health. We are very far from identifying the elements in either urban air or cigarette smoke which favour the onset of respiratory disease, but it seems that both are concerned to varying degrees in chronic infections and malignant changes in the respiratory system. In the paper already quoted, Farr sums up the implications for community action very appropriately: " It has been shown that external agents have as great an influence on the frequency of disease as on its fatality; the obvious corollary is, that man has as much power to prevent as to cure disease."

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HAZARDS FROM AIR-BORNE RADIOACTIVE MATTER

by

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FOR more than fifty years it has been known that the atmosphere contains a variable amount of the gas radon and its products. This natural radioactive matter is short-lived but is continually renewed from primary sources in the ground, and from the surface of brickwork and stone. Although providing no radiation hazard in the open air, these natural components have to be taken into account when the effect of man-made additions is assessed.

The development of nuclear science is now bringing more disturbing possibilities of contamination by radioactive matter, ranging from the large zone of dangerous fallout created by some types of nuclear explosion, to the traces of fission products, spread globally from numerous tests, which are detectable in soil and food. The term hazard is an understatement for the degree of risk in the immediate vicinity of an explosion, and it is here applied to the more wide-spread fallout, a new form of air pollution which has given rise to much anxious discussion. There is at present no sure biological knowledge of the hazards which might be associated with exposure of whole populations to environmental contamination from fission products in amounts of the order 10 or 100 times those now found, so that interpretations tend to vary with ethical and political viewpoint.

Apart from tests in distant parts of the world, there are more local sources of contamination which could originate in this country, and in others, such as emission of radioactive matter during the re-processing of irradiated uranium, or accidents to reactors. The number and variety of nuclear installations is increasing, and every precaution will be needed to limit the possibility not only of major accident but of persistent contamination at relatively low levels. The nature and effects of any such potential pollutants are matters of special concern to members of this Society, and indeed to all advocates of a clean and safe atmosphere.

Evaluation of the extent to which man-made radioactive matter is present in the atmosphere, and the effects of its subsequent deposition on the ground, can only be made through specialized radiochemical studies. These have been undertaken by a few research establishments, and some local authorities and public analysts are also exploring the possibility of monitoring conditions in their own areas. At the time of the Windscale accident, many local authorities throughout the country, who make regular determinations of smoke in the atmosphere, provided filter papers for an assessment of their radioactive content to be made in the laboratory of the London County Council and subsequently a more detailed examination was made at Harwell.

Natural Atmospheric Radioactivity

We are always exposed to a small background of ionizing radiation coming from the ground, from the walls of buildings, and from the cosmic rays, the amount depending on situation but being fairly constant in any particular place. In comparison with this background, the amount of direct radiation received from air-borne matter is quite trivial. The fraction of this air-borne matter retained in the lung provides an appreciable local addition to the radiation dose otherwise received, although there is still no reason to suppose the dose to be hazardous, except in special situations such as uranium mines where the radon concentration is frequently many thousands of times that found in the atmosphere.

Uranium and thorium are widely distributed in the earth's crust and in building materials. These primeval elements undergo slow processes of radioactive change, being transformed through a series of other chemical elements into the metal lead. The numerous intermediate products include three isotopic gases named radon, thoron and actinon. These are formed as members of three separate decay chains headed respectively by uranium-238, thorium, and uranium-235. When " born " at a surface, the gaseous atoms can diffuse into the atmosphere where they remain for a period before transforming again, this time to a solid form which adheres to other solid matter such as dust particles suspended in the atmosphere. In the case of radon, the average period of survival is several days, although 6 per cent. of the atoms present at any time last for at least another month. Thoron atoms are formed in approximately the same numbers as radon atoms, but because the life of thoron averages little more than a minute, the gas cannot diffuse from any great depth in soil, and the proportion found in the atmosphere is quite small. From the relative abundance of the two uranium isotopes, it can be deduced that actinon is formed at source in the proportion one atom to every 22 atoms of radon. Its lifetime averages only a few seconds and it has not been specifically detected in the atmosphere.

The amount of radon in air varies with locality and meteorological conditions. Since the gas originates at or near the ground, a greater concentration builds up in a calm atmosphere. The diurnal variation in turbulence, associated with the tendency for air to rise from warm ground, is reflected in lower average values of radon in the early afternoon as compared with the hours before sunrise.[1] This relationship between concentration and turbulence prompts the suggestion that regular measurements of atmospheric radioactivity might be of value in interpreting data on pollution by smoke and sulphur dioxide, since the concentration of these pollutants is governed not only by the quantity emitted by chimneys, but to a large extent by the prevailing degree of dispersion. Dispersion is always low in fog, and the worst smogs are characterized by phenomenally low dispersion. The occurrence of a bad smog in our prospective smoke-controlled future would be an unexpected and discouraging event. However, by using turbulence as a yard-stick, there might be a consoling possibility of finding that the meteorology on such an occasion had been exceptionally unfavourable, and that but for the smoke control measures the smog would have been even worse!

Determinations with which the author is directly familiar have shown amounts of radon present in London air ranging from 0·01 to 0·5 micro-microcurie per litre, under weather conditions varying from very fresh in the month of May to persistent fog in December. The amounts of thoron have varied over a rather smaller range with a mean of about 0·001 in these units. Expressed in volumetric units this maximum radon concentration is 0·33 parts per million million million, which implies so few atoms that a better mental picture may be obtained by enumerating them. Consider for example a radon figure of 0·057 micro-microcurie per litre, which is fairly representative of published results.[2] Calculation shows this to be just equivalent to 1,000 atoms of radon per litre of air. The half-life of radon is nearly four days, which means that half the number of atoms originally present disintegrate in this period, throwing off a relatively small fraction of their mass as an ionizing particle. Owing to the random occurrence of these events, the precise number of atoms disintegrating during a period of time cannot be predicted, but calculation shows that in a swarm of 1,000 radon atoms, there would be, statistically, an even chance of the number transformed in the first hour being between five and 10.

On disintegration each radon atom is converted to radium A, and almost immediately becomes attached to a dust particle. The new atom has a probable life of only a few minutes before being transformed to radium B; and in the course of a few hours the decay process continues through radium C, and C′, to the relatively stable radium D. These five transformations produce a total of three alpha particles, two beta particles, and some gamma rays. The frequency of the occurrences is too low for their reliable measurement in as little as a single litre of air, and the procedure most commonly employed is to isolate the radon daughter products by filtration of about a cubic metre of air, and then to count the number of particles emitted from the dust on the filter. The continuous decay during filtration, and counting, presents a complex picture for interpretation, and mathematical expressions applicable to this case have recently been derived and reduced to their simplest form.[3]

The volume of air breathed in a day is about 20 cubic metres. When all factors are taken into account, including the retention of alpha emitters in the lung, the degree of ionization of body cells from radon and its products is too low to give any cause for concern. In the comprehensive Medical Research Council report of 1956,[4] a very much higher figure for radon in the air of large cities was admitted as a possibility, in consequence of one study made at a cancer research institute in London. The figures reported from this investigation were not in accord with most other published findings and the technique used may deserve further examination. A suggestion was offered that the abnormally high figures might be due to radon released during the combustion of coal. However, if consideration is given to the normal amounts of sulphur and of radon in coal, and a dilution factor is deduced from the measurable amount of sulphur dioxide in the atmosphere, it appears that radon from this source could not contribute any appreciable part of the amount reported to be found.

Air-borne Dust From Weapon Tests

In recent years, fission products from distant test explosions have in varying amount been continuously present in the atmosphere. Following one test, more fully documented than usual, the early fallout created a dangerous area covering many thousands of square miles. Only the distant fallout, involving delayed and world-wide distribution of fine debris, from this and other episodes, will be discussed here.

The atmosphere below about 10 miles in height, called the troposphere, is a region in which there is turbulence and rainfall. An atomic bomb of "nominal" (20 kilotons) energy release contaminates this region with debris which is deposited or brought down by rain within a period of a few weeks. The megaton type of explosion, (with energy equivalent to millions of tons of TNT) carries debris as high as 20 miles, into the region called the stratosphere where there is no turbulence or rainfall. Here dust can remain for many years before its slow settlement brings it into the troposphere. Samples taken on stratospheric flights show there is a considerable reservoir of radioactive dust at great heights. This is descending into the lower atmosphere at a rate of the order 10 per cent. to 20 per cent. per annum, and even in the absence of further additions it must continue to trickle down for years to come.

These traces of fission products can be detected in the atmosphere near ground level at all times by filtering them from large volumes of air. When test explosions take place in the northern hemisphere, a temporary increase in activity is observed as the affected air mass, moving eastward round the world, passes over this country. The time taken to arrive from Nevada is usually five days, and is fourteen days or more from Russia. Occasionally the cloud causes a second appreciable rise in measured activity, lasting for a few days, after it has made another complete passage round the world.

In observations made over several years at County Hall, London, the activity from long-range fallout, measured in terms of the number of beta particles emitted each minute in a cubic metre of air, has always been less than the radon activity, and is on the average only 1 per cent. of this natural activity. It should be borne in mind that these residual fission products have long lives compared with radon and daughters, so that from each daily volume of air inhaled, from which a fraction of the dust burden is retained in the body, the fission products eventually provide a large number of beta particles. On the other hand the alpha particles emitted by radon and two of its daughters are ten times as damaging in certain circumstances as the beta particles. The overall conclusion is that the total effect from direct inhalation of long-range fallout is no more significant than that of the short-lived natural component.

A more debatable aspect is that of pollution of the soil, and indirectly of food, by the cumulative deposition of air-borne fission products.

Of the many radioactive products formed during an explosion, only a few survive in quantity for more than a year. Of these, two have greater biological significance than the others, and only these two need be discussed. They are strontium-90 and caesium-137, each having such a slow rate of decay that their activity is reduced by only a small percentage each year. Grazing animals ingest appreciable amounts of rain-deposited fission products. Strontium, because of its chemical similarity to calcium, is retained in bones; caesium, like sodium and potassium, is found in other tissues and particularly in muscle. In the southern hemisphere, where fallout has been less than in the northern, the amount of strontium in sheep bones is also less. It can be mentioned that it was ascertained in the L.C.C. laboratory that English and New Zealand lamb could usually be differentiated by this property. Figures published by the research group of the Atomic Energy Authority show that marked variations occur within this country due to factors such as rainfall and degree of chalkiness of the soil.

Both strontium and caesium are found in cow's milk, and this is one of the principal sources of human ingestion of these fission products. Measurements of the amounts present in human bodies and in bones have been made in a few laboratories, and some of these figures were quoted in the M.R.C. report. More recent figures now available do not change the picture much. It appears that the radioactivity due to caesium in the human body is less than that from natural potassium in the body; also, the effect of strontium deposited in human bone is less than that of radium in bone, this radium being derived mainly from food.

Persistent Discharges of Radioactivity

Reactors are now being operated for such diverse purposes as the generation of electricity, the production of nuclear explosives, and the production of radio-isotopes for medical and industrial purposes, the plants differing in design as well as function. The earlier models of reactor have greater potentialities for air pollution than later designs; in the early stages of development the sociological implications of nuclear energy, and the ultimate benefits hoped for, were so far-reaching that it appeared justifiable to take this calculated risk.

In a reactor such as the Harwell BEPO, the cooling air passing through the pile is exposed to a strong flux of neutrons, and the component gases of the atmosphere are activated. The one most affected is argon, which is present to the extent of 1 per cent. in air. When BEPO is operating at the maximum power of 6 megawatts, the hourly discharge of hot air from the 200 ft. chimney contains 50 curies of argon-41, an isotope with half-life 110 minutes. Filters remove any activated particulate matter, but there is no practicable method of removing argon. The piles at Windscale presented a similar case on a larger scale.

For the prolonged exposure of a large population to an atmosphere containing radio-argon, the concentration recommended by the International Commission on Radiological Protection as being the maximum permissible is equivalent to 50 curies per cubic kilometre of air. The efflux of air from BEPO is stated to be 3·2 by 10^5 kg. per hour, and it can be calculated that a dilution factor of 4,000 would be needed to reduce the radioactivity of the chimney effluent to the acceptable limit. Direct measurements made at Harwell[5] have shown that, averaged over a number of different atmospheric states, this degree of dilution is achieved, nearly enough, at the place about 1,000 metres downwind where the greatest short-period ground-level concentration occurs. Because wind directions vary, the average concentration at any one place is very much less. It is also relevant to mention that the built-up area at the site extends only 500 metres from the chimney so that the total factor of safety is large.

It is of interest to use this experimental data to make comparison with a hypothetical case of a chimney of the same size, serving furnaces burning approximately 20 tons of coal an hour. Thus: supposing chimney gases to be emitted in the same volume and at the same temperature (50°C.) as the air from BEPO, and these contain 0·1 per cent. by volume of sulphur dioxide. Then: assuming the dilution factor of 4,000 at a distance of 1,000 metres, the maximum ground-level concentration windward of this source would be 0·25 parts per million. This figure is of the order to be expected from measurements of the more classical form of pollution.

Although emission of radio-argon from air-cooled piles is unavoidable, precautions can be taken to limit the discharge of activated dust from structural materials, or fission products from surface-contaminated or leaky cans. Instruments give early warning of such troubles, and there are filters to retain particulate matter from minor mishaps. The later designs of reactor have closed-circuit cooling systems, using pressurized carbon dioxide in the Calder Hall type of plant and liquid metal at Dounreay, so these do not involve any discharge to atmosphere.

Another potential source of pollution which must be guarded against is the release of gas and vapour when irradiated fuel elements are dissolved in nitric acid for re-processing. In the United Kingdom the sole plant of this type is at Windscale, although next year there will be another operating at Dounreay. Chemical processing of uranium from reactors has to be undertaken periodically, either to remove the desired product, if this should happen to be fissile plutonium, or to remove fission products which, by their capacity for absorbing neutrons, tend to " poison " the uranium. An important factor in reducing the activity of such gases is the time allowed for storage of the canned metal after removal from the reactor. A long " cooling " period is needed to reduce the activity of xenon-133 and iodine-131 which have half-lives of five days and eight days respectively. Xenon is chemically inert and therefore difficult to remove, although iodine is reactive and can be scrubbed out. Radioactivity due to another inert gas, krypton-85, is not diminished appreciably as it has a half-life of 10 years. If extensive use of fission processes continues, this gaseous isotope could cause a world-wide problem in a decade or so unless steps are taken to trap it at source.

Radio-iodine is notoriously troublesome for a number of reasons. It is one of the more abundant products of the fission process, and is also formed as the disintegration product of another volatile element, namely radiotellurium. Iodine has special physiological significance as it is easily assimilated into the body and concentrates in the thyroid gland. When present in the atmosphere it contaminates pasture and hence milk. Because of the possibility of ingestion by this indirect route it has been estimated[6] that the maximum permissible concentration in air based on inhalation risk should be reduced by a factor of the order 1,000 in the case of persistent atmospheric pollution by radio-iodine. It is probable that with strontium, caesium, and some other radioisotopes, ingestion through food chains is again the prime consideration, and the limits defined by the I.C.R.P. as being tolerable for breathing are not sufficiently stringent where there is widespread pollution of the atmosphere.

Accidental Release of Radioactive Matter

The Windscale accident gave a salutary reminder that, despite the care and skill with which nuclear installations are designed and controlled, the unexpected can still happen. At the same time it is reassuring that this major accident, though causing irreparable damage to the reactor, was not destructive of life or limb nor was there any demonstrable harm to health. In terms of the stringent standards which are applied to radioactive matter, the degree of pollution of the nearby countryside was serious, and to avoid any possible hazard about a quarter of a million gallons of milk was sent to waste.

An official report[7] on the cause and nature of the accident is available, and it has also been stated[5] that comparative measurements were made of the extent to which the air had been contaminated in various parts of the country. For this survey, smoke filter papers for the relevant dates were collected from authorities who collaborate in the D.S.I.R. investigation of atmospheric pollution, and their activity was measured in a standardized manner in the L.C.C. laboratory. The results showed that the radioactive matter discharged from the Windscale chimney had travelled in a south-easterly direction as a diffusing cloud. A fortunate circumstance was the absence of any appreciable rainfall over the country as a whole.

An electrostatic filter is employed at County Hall to separate material for analysis from several thousand cubic metres of air. However, it was found on this unique occasion that alpha, beta, and gamma activity, attributable to various components of the accidental discharge, was measurable on filters through which a single cubic metre has been passed. In such measurements allowance has to be made for the natural radioactivity.

Filters in the Windscale chimney prevented much of the " smoke " liberated from the overheated region of the pile from escaping to atmosphere, although they could not so effectively hold back volatile constituents such as tellurium and iodine. For this reason, and because of the low tolerance concentration in air already mentioned, attention was focused on iodine as the primary contaminant. The isotopes concerned emit gamma radiation which is sufficiently penetrating to be detected in a fairly large bulk of milk so that direct measurement of the amount in a churn was feasible. If the permissible limit had been determined by the content of plutonium or strontium, field testing would have been much more difficult.

London deliveries of milk were found for a short period after the accident to contain detectable amounts of radio-iodine, but these did not exceed 0·01 microcurie per litre. No restrictive action was taken as the iodine did not exceed one-tenth of the amount considered to be safe for consumption over a limited period. It was estimated in the same laboratory that the total amount of radio-iodine inhaled by an individual in any large centre of population was not much more than 0·01 microcurie; the maximum figures of the data available related to Lancashire and the West Riding. This " dose " can be viewed in the light of the fact that amounts of radio-iodine ranging from a few microcuries to several thousand microcuries are commonly administered for medical purposes. Comparison can also be made with the fact that the permanent radioactivity of the human body, due mainly to natural potassium, is about 0·1 microcurie.

Monitoring of Radioactivity

The Windscale accident of October 1957 is the sole example in this country of loss of control in the operation of a reactor. Although the specific occurrence was obviously not anticipated, the implications of such a release were well recognized and had been discussed in terms which closely foreshadowed the event at the 1955 Geneva Conference on atomic energy. Reactor accidents causing greater environmental contamination and perhaps even loss of life can be envisaged, as is the case with many industrial undertakings dealing with hazardous materials and discharging chimney effluents. It is therefore reassuring that, following the advice of the Fleck Committees, action is being taken to reinforce health and safety measures. At the same time the need is acknowledged for close liaison between reactor operators and authorities in the vicinity who have responsibility for public safety.

At present the Atomic Energy Authority itself is the only body having, on the requisite scale, the trained staff and instrumental facilities needed to monitor acute or chronic cases of radioactive contamination, and it may be thought that some benefit might derive from having one or more independent authorities equipped to collaborate in such checks. At certain levels this work would be within the competence of larger health authorities, having laboratory facilities, although it would be desirable to have direction and co-ordination at central government level by specialists in the subject.

The approach towards clean air is being made on many fronts. Good progress is being made in the reduction of smoke, although the problems of eliminating sulphur and nitrogen oxides seem intractable. There is every hope and prospect that in years to come fossil fuels will be largely replaced by nuclear sources of heat and electricity, obtained through inherently safe devices, possibly using a thermal fusion process. It is therefore logical and appropriate for this Society to initiate or support any steps which may mitigate the present potential hazards from nuclear installations, and to hail with enthusiasm the advent of clean and safe processes.

(The author acknowledges with thanks permission given to quote from reports of the Scientific Adviser to the Medical Officer of Health, London County Council, and wishes to state that the opinions here expressed are those of the author and not necessarily those of the London County Council.)

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AN AUTOMATIC SMOKELESS STOKER FOR CENTRAL HEATING

by

D. V. Brook and

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(*British Coal Utilization Research Association*)

THE problem of firing central heating boilers in blocks of flats, public buildings and similar premises has become more difficult with the passing of the Clean Air Act. Hand firing with large coke is still possible, of course, but even before the passing of the Act there was a tendency for hand firing to be replaced by mechanical stokers in order to avoid high labour charges. Most of these mechanical stokers used coal, because of various economic and technical factors.

Under the Smoke Control Areas (Exempted Fireplaces) Order, 1957, fireplaces designed or adapted for the combustion of liquid fuel are exempted from the provisions of Section 11 of the Act (which relates to smoke control areas), provided that they are so installed, maintained and operated as to " minimize " the emission of smoke. No similar exemption has yet been given to any mechanical stokers for firing coal, but clearly some provision will have to be made if it can be shown that certain types of mechanical stoker can burn coal with very little smoke emission. It is obviously undesirable from the national point of view that the smoke control areas should be made dependent upon imported oil while supplies of coal are freely available.

It should be remembered, moreover, that there is substantially less sulphur in coal than in the oil used for larger heating installations, and that some of the sulphur in coal remains behind in the ash. So far as atmospheric pollution by oxides of sulphur is concerned, therefore, coal may be preferable, even taking into account the fact that a ton of oil is thermally equivalent to more than a ton of coal.

Since smoke control areas will largely be created in city zones containing a substantial proportion of large residential, commercial and public buildings, the heating requirements of these buildings constitute a major problem for the owners and for the local authorities (who are frequently also the owners).

It must be assumed that a high degree of smokelessness will rightly be demanded from any firing equipment in a smoke control area, and that mechanization will not in itself be considered a sufficient proof of suitability. Mechanization and automation should be judged not only by their ability to reduce the cost of an attendant skilled fireman, but also by the extent to which they provide substantially smokeless operation by automatic means which are independent of the human element.

The Domestic Appliance Department of the British Coal Utilization Research Association has been working on this problem for some time, since special design and operational factors arise with the very small mechanical stokers required for central heating in residential premises. The present Report is a brief indication of the progress being made, particularly in relation to smoke emission.

Attention has been focused on the chain grate type of stoker, for two reasons. In the first place it is the kind of stoker which has achieved the greatest degree of smokelessness in large industrial units. Secondly it can burn with ease the small coals ($\frac{1}{2}$ in.—0) which are likely to form an increasing proportion of the total output as mechanized methods of mining extend. There is also the advantage, of course, that the smaller sizes of coal offer a greater financial incentive to offset against the cost of mechanical stokers. In spite of this the design of the stoker and its control system have to conform to much stricter cost standards than are permissible with the larger industrial versions.

It has been assumed that, in order to bear comparison with oil firing, the mechanical stoker for a block of flats should need only occasional attention from an unskilled man. In fact the aim has been to reduce the human operations to the bare minimum of trimming the coal bunker occasionally and removing the ash every 12 hours. Additional mechanization to obviate the need for these operations would probably be uneconomic, as the number of man-hours involved is small. The modern trend is to group blocks of flats into "estates"; in these cases labour has to be provided for such jobs as grass cutting in summer, and there is usually no difficulty in finding two or three man-hours per day for unskilled work at the heating plant in winter. Anything which required frequent attention by a skilled fireman would be viewed with great disfavour, however.

Preliminary work in the B.C.U.R.A. laboratories with a miniature chain grate stoker showed that special design considerations were involved with grates of such small width, since the "side effects" became more predominant than is the case with larger industrial versions. There was, moreover, the problem of achieving "banking" at one tenth the normal full rating of the stoker. This meant that the fire had to be retracted under the ignition arch, leaving part of the grate uncovered by fuel, whereas industrial chain grate stokers are not expected to achieve such a wide load range and can be operated in such a way as to keep the grates covered along their whole length. The necessity for operating with part of the grate uncovered introduced the need for some automatic means of restricting the area of grate through which air was blown, since otherwise the efficiency of the unit would suffer severely.

The degree of smokelessness in the early model was definitely not good and it was found necessary to redesign the ignition arch and guillotine assembly, and to devise different means for the introduction of secondary air.

Stokers were then constructed in the B.C.U.R.A. workshops and to new designs by the research staff. A photograph of one of these units is shown in Fig. 1. The grate width in

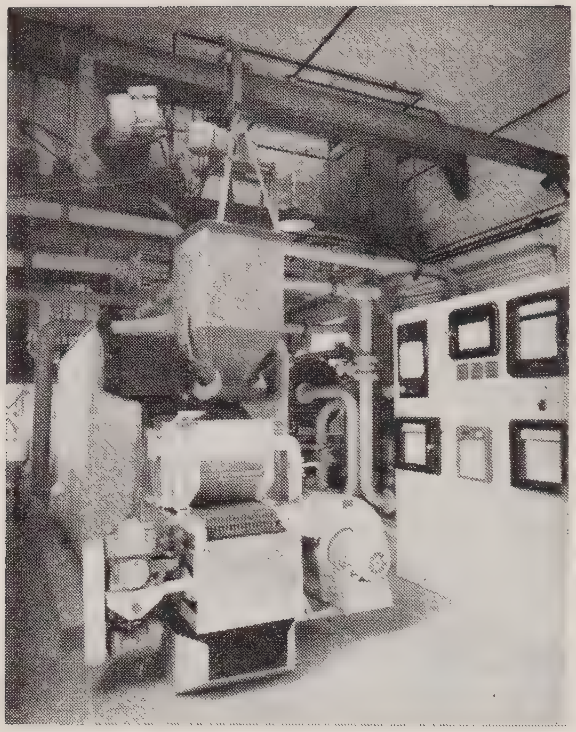

Fig. 1. Experimental Stoker and Boiler

this case is 18 in., and the stoker is shown in the 1,324,000 B.t.u./h. sectional boiler which it is designed to heat.

The automatic fuel-recording hopper above the stoker, the elaborate instrument panel and the calorifiers and cyclone dust catcher in the background are, of course, purely for experimental purposes and would not be necessary for an actual installation in a block of flats. The coal conveyor feeds coal directly from the storage bunker to the stoker and operates automatically according to the amount of fuel required.

These stokers incorporate novel means of automatic control. The usual industrial system of fuel/air ratio control necessitates human adjustment when either the fuel characteristics change or there is a variation in the combustion conditions (such as air leakage at the sides of the grate).

In a fully automatic stoker means must be provided to ensure that at no time does hot unburned fuel get discharged over the rear end of the grate with the ash; this could be caused by having too little air. On the other hand there must never be a large amount of excess air blowing up through an uncovered rear portion of the grate when the length of fuel in combustion decreases.

Fig. 2 shows the interior of an 18 in. stoker with the chain grate removed. The length of grate to which primary air is supplied is varied by means of dampers which are automatically adjusted according to the length of fire on the grate. The amount of primary air is also adjusted by the same means. These control methods have been the subject of recent patent applications and will be published when the development work is completed.

It is sufficient at this stage to report that there are excellent prospects of completely automatic operation. What is perhaps more important in the present context is the degree of smokelessness achieved. Fig. 3 shows the optical density of the smoke in the 14 in. stack for a series of burning rates from banking at 16 lb./h. to full rating at 160 lb./h.

It will be seen that the optical density is at no time greater than 0·03 (7 per cent. obscuration), and when one considers that Ringelmann 2 corresponds to 50 per cent. obscuration (optical density about 0·3), it will be appreciated that a high degree of smokelessness has already been attained. That this is not due to dilution of the chimney gases by large quantities of excess air can be seen from the corresponding CO_2 figures on the same graph. Where zero smoke emission is shown in Fig. 3 the smoke density is so low that it cannot be detected even with the very sensitive recorders which have been developed for research purposes by B.C.U.R.A. At low and medium burning rates the smoke is completely consumed by the combined effect of the primary and secondary air, the latter issuing as preheated jets from openings in the hot ignition arch. Further research is likely to reduce even more the very small amount of smoke emitted at the higher burning rates.

These small automatic stokers are not yet commercially available and the

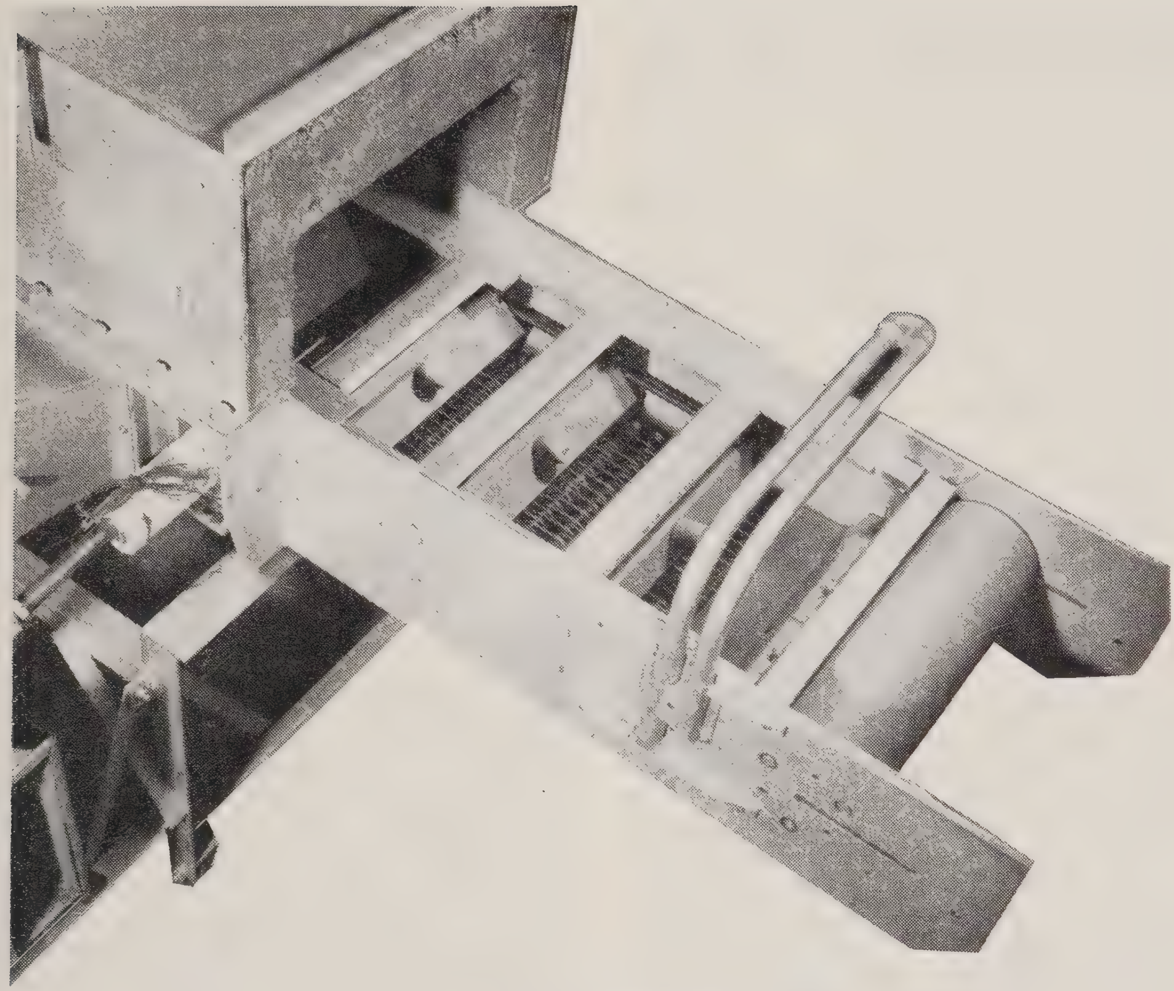

Fig. 2. Control Dampers in Stoker

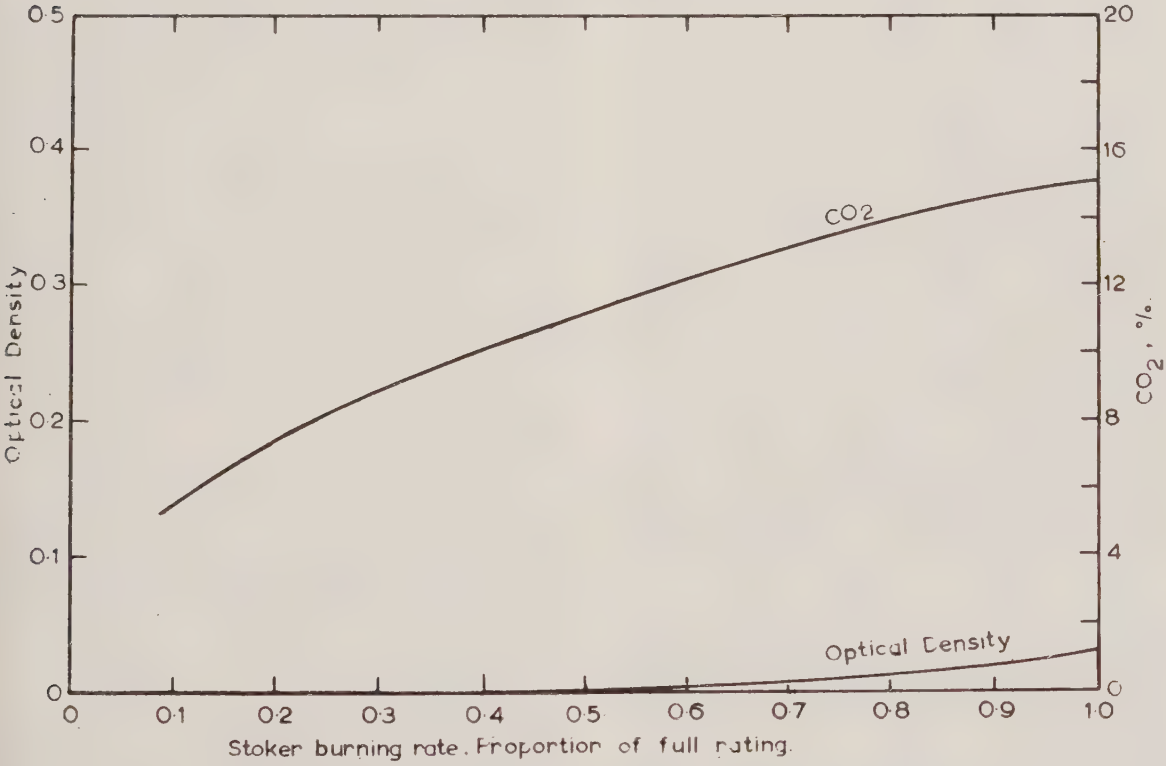

Fig. 3. Smoke emission and CO_2 related to stoker burning rate.

question of their manufacture can only be considered when the development work is satisfactorily completed, both in the Leatherhead laboratories and in field trials.

The potential market for such a stoker is large. Figures supplied by the manufacturers of cast iron sectional heating boilers in the range 500,000 B.t.u./h. to 2,000,000 B.t.u./h. indicate that about 5,500 of such boilers are manufactured each year, and that about 95,000 are now in use. If all these boilers were to use coal, the annual consumption would be about 12 million tons.

Clearly there would be certain types of installation where a coal-fired stoker would not be practicable even if automatic, for reasons of fuel storage, non-availability of labour, or other factors. The size of the gross potential tonnage shows, however, that this is a problem affecting the national fuel economy as well as the implementation of the Clean Air Act.

This work is part of the programme carried out in the Domestic Appliance Department, and the paper is published by permission of the Director General of the British Coal Utilization Research Association.

Discussion

C. H. G. Hayward (Edwin Danks & Co., Ltd.) stated that he had been interested to hear Dr. Burke's presentation of his paper and to say that he was astonished with the contents would be an under-statement.

Towards the end of the paper it was stated that the stoker was not yet commercially available and this had been again repeated by Dr. Burke. The impression, therefore, might be gained that a small chain grate stoker of this type was something new. Apart from the fact that his Company had provided B.C.U.R.A. with the original stoker on which most of the present paper was based, there were at least 100 of these stokers in operation. The 18 in. grate referred to was the width always used, due to the fact that the stoker usually had to fit into an existing hand firing door. He had not had an opportunity of seeing the latest B.C.U.R.A. stoker but from the photograph in the pre-print it appeared to incorporate features which were part of the original design and which were the subject of patents held by his Company. The need for automatic control had always been recognized, particularly for low load operation, and this was, in fact, a standard part of their equipment. Automatic handling of coal and ash was a very difficult problem, even in the larger stoker. The small stoker presented an even greater problem as the cost might not only be greater than the cost of the stoker but even greater than the cost of the boiler.

In considering the small stoker for heating offices and small industrial and commercial premises it was sometimes found that due to the cost of delivery of the small amount of fuel burnt, and the additional cost of removing the ash from the usual basement, the stoker was at a disadvantage. This, of course, applied mainly to very closely built up areas, and particularly in the southern part of the country where the delivery price of coal was very high. Where these difficulties did not exist an appreciable saving could be made. The grouping of blocks of flats referred to in the paper was, of course, very common in Scandinavia but in these cases the heating boilers were considerably larger than those which could be equipped with these very small stokers. There was, however, a demand for these machines in the horticultural industry where fuel costs were the second largest item in total production costs. In addition to making a very substantial reduction in fuel costs this type of equipment also completely met the requirements of the Clean Air Act. These machines were also being used in certain types of industrial furnaces where dark smoke emission was often a problem.

With regard to Mr. Goodfellow's following remarks on underfeed stokers, Mr. Hayward pointed out that with unsatisfactory operation it was possible to make considerably more smoke with oil firing than with mechanical stokers using solid fuel.

J. Goodfellow (C.P.H.I., Leeds) speaking on what he described as the ill advised campaign for the exemption of underfeed stokers in proposed Smoke Control Areas said that an unconditional exemption would leave the reputation of the appliance in the hands of any conscienceless user, who chose to continue using it in a state of disrepair, or who took no steps at all to secure the proper rank of fuel.

We had been assured, on the highest authority, that well maintained underfeed stokers, when using the correct rank of bituminous coal, were virtually smokeless. If that was a statement we could accept, then there was no case for the exemption of underfeed stokers, and the efficient user of the underfeed stoker had nothing to fear in a smoke control area, and needed no special defence. But local authorities must not be deprived of their power to deal with the inefficient and careless user who would sabotage the smoke control area and dishonour the reputation of a most useful appliance.

A. Houlbrooke (Public Analyst, Staffordshire C.C.) said that the papers read by Dr. Reid and Mr. Courtier showed how important it was that they should preserve a sense of proportion regarding the relative effects of the different types of atmospheric pollution. While radioactive " fall-out " was news it was, nevertheless, obvious that the incidence of respiratory disease was many thousands of times greater than injury, or risk of injury, due to radio active material. It was ludicrous —but also dangerously misleading—to hear prominent women speakers wailing about the months of agony suffered by mothers-to-be at the prospect of bearing children who would be damaged by radio active " fall-out "!

Mr. Courtier stated what the L.C.C. was doing as regards the detection and measurement of radio active matter. It should be realized that other local authorities had available the scientific personnel who, if necessary, would undertake similar work in their own areas.

Dr. S. R. Craxford (Fuel Research Station) referred to Fig. 5 in the paper by Mr. Pindard and Dr. Wilkins, which shows the concentration of smoke in the City of London to be very much less than in the surrounding boroughs, and said that this demonstration of the value of a smokeless zone indicated that dispersion of smoke in an upward direction by atmospheric turbulence is more important than sideways drift near ground level. This was confirmed by Fig. 7, which showed that a persistent low level inversion increased the concentration of smoke in the City in such a way that according to the figure it no longer formed an island site of relatively low pollution surrounded on all sides by more polluted areas; under these conditions sideways drift becomes the more important factor. This raised the question as to whether many " smokeless zones " or " smoke control areas " could fulfill one of the main functions for which they were introduced, *i.e.*, to protect their inhabitants from the building up of large concentrations of smoke during temperature inversions. Incidentally, in the case of the City, too much emphasis should not be placed on the " smokeless zone "; emission of smoke in the City has always been low and of the three smoke filters marked in the City area in Fig. 5, the only one that had been in operation for more than three years showed just as low smoke concentrations ten years ago as it did today.

Dr. Craxford also referred to the point raised by speakers in the discussion as to the dangerous constituents of smog, and said that more careful consideration should be given to the possibility that ammonium sulphate aerosols were among the more harmful, as first suggested by Dr. Hemion. Ammonium sulphate is strongly acid and could form points of acidity in the lung that could cause damage before they could be neutralized by the body fluids. By itself, sulphur dioxide oxidizes very slowly in the air but when combined with ammonia the rate of oxidation is rapid, so that the high sulphate concentrations observed during smog were more likely to be due to ammonium sulphate than sulphuric acid. In town air most of the ammonia probably arises from coal fires in amounts roughly proportional to the amount of smoke, so that the observed correlation of mortality with smoke concentration was consistent with the view that ammonium sulphate is responsible for the deaths. It is not inconsistent with the view that *neutralization* of the air with ammonia, which required more than the stoichiometric quantity, might give relief to bronchitics during smog, but it suggested that particular care should be taken to ensure that sufficient ammonia was added, or the mixture might be more dangerous than the original polluted air.

G. W. Dhenin (Deputy C.P.H.I., Bath) expressed his pleasure at such a unique contribution as given by Mr. Courtier at this informative technical session on air pollution. The Conference Committee was to be commended for its progressive and far sighted outlook in including such a paper in which the hazards to health from airborne radio-activity were placed in their proper perspective and in direct line with the objects of the Society in desiring Clean and *Safe* Air.

Mr. Dhenin said that we should be very thankful that the new industry had grown up with such a strict scientific control and with such a large factor of safety. Instrumentation in research plant and power stations was first class and adequate; might it always be so. He wondered, however, whether some such recording instruments should be maintained in the vicinity of groups of smaller factories and plant where radio-isotopes were used in various processes.

It was fair to say that the most likely source of radio active airborne pollution was from the nuclear fuel reprocessing factories such as Capenhurst, rather than from the reactors themselves and the use of radio-isotopes.

Any increase in the level of radiation deliberate or accidental, was a serious matter. They could only withstand a fairly small amount of radiation and when radio-active material got inside the body by ingestion, inhalation or through cuts and bruises, then it was far more dangerous.

The commencement of the present nuclear age was in direct contrast to the beginning of the industrial revolution when anyone who wanted power could use coal freely, and no one seemed to realize that pollution from coal was any more than merely objectionable.

Fortunately the technique of the new power industry was in the hands of experts who might be trusted to never lose sight of the dangers.

Many local authorities were carrying out routine smoke filter sampling. Mr. Dhenin wondered how many of these authorities had been asked to submit these filter pads for tests for radio activity and had there been established a datum line for various parts of the country.

When nuclear energy plants and their ancilliaries became more numerous and the use of radio-isotopes extended, questions involving the health hazards would certainly have to be externally supervised, and by " externally " was implied outside the perview of the Atomic Energy Authority, and that would involve Local Authorities who had the necessary facilities and staff. Perhaps monitoring of food, water, soil, plants and animals as well as the air might be then indicated.

Mr. Dhenin asked Mr. Courtier to give the Conference some idea of the type and scale of monitoring which was already being carried out at the Scientific Adviser's Department, London County Council and whether collation of results for all over the country would be possible.

K. L. Spence (Assistant County Health Inspector, Warwickshire C.C.) said that he was afraid that from what he had heard during the conference all we might obtain was a " clear atmosphere " not clean air. His experience of clean air or the lack of it had been obtained the hard way. Seventeen years ago he came out of the army with asthma, which, by the use of anti-histamines, etc., was kept under control. But—in spite of the suggestion that sulphur dioxide was not harmful unless in the presence of smoke or grit, he could assure the speaker that he could certainly feel the effects of a sulphur polluted atmosphere.

Mr. Spence said he would like to appeal, not as an Officer of a Local Authority, but on behalf of Dr. Reid's " respiratory cripples," to our scientists and industrialists to tackle the problem of sulphur and its oxides. He referred to Dr. Reid's closing words in his paper " . . . man has as much power to prevent as to cure disease " and suggested therefore, that it should not be beyond their powers to reduce the sulphur content of *all* our fuels, and thus with the control of smoke and dust emissions have a truly clean air.

Dr. W. J. D. Cooper (M.O.H., Central Gloucestershire United Districts) said that they in Public Health were always recognized as the guardians of health of their local population. Yet, in relation to the potential dangers to health from radio-activity they were kept in the dark. At a conference on " Radiation Hazards and Public Health " which he attended in April, Sir Ernest Rock Carling said " since radio-active hazards were not detectable by any of the senses, the Medical Officer should know the whereabouts of potential dangers."

How could they know where the potential dangers were in their areas if there was no information available. It was for that reason that he made a plea for the registration by Local Authorities of all users of radio-isotopes in industry and where used for other purposes.

Dr. Cooper said he was amazed the previous week when he read in his *Medical Officer* of a startling report from the Radiological Protection Service on the state of one luminizing shop, showing that in that particular establishment, through ignorance of the real nature of the hazard—" the linoleum top of the desk was found to have surface contamination sixty times greater than the recommended maximum; the facing edge of the luminizer's bench one hundred and fifty times; the lampshade eighty times; the seat of the luminizer's chair sixty times; the back of the seat forty times and the cover of the log book sixty times."

He had also heard of outworkers receiving luminizing work in their own homes, where even their children can become contaminated with that dangerous material.

When that could happen in the factory, he wondered where the radio-active waste material was disposed of and what water supplies it was likely to contaminate.

Dr. Cooper said he was the Medical Officer of Health to five Local Authorities in Central Gloucestershire and although there was no official information he knew that radio-isotopes were being used in some of the small engineering industries in that area. In his area there was also under construction an Atomic Power Station at Berkeley. In relation to that they were now organizing a Liaison Committee with the Central Electricity Generating Board, which might prove very useful in co-ordinating the interests of public health.

It was rather startling to think that in pre-war days the total radium in the world amounted to 2,000 curies and today the amount of radio-activity in some of the nuclear power stations would be as much as 300 to 500 megacuries.

He realized that the hazard depended as much on containment and mode of handling as on the amount concerned, but in view of the method of handling that he had mentioned earlier, he felt that he must make a strong plea to this important Conference that a resolution be sent to the Ministry of Housing and Local Government for the Registration already mentioned.

He suggested that the Resolution might read:

> " THAT this Conference requests H.M. Government to expedite legislation whereby users of radio-isotopes must register with the Local Authority."

The Chairman stated that it would not be in order for the suggested Resolution to be moved, as previous notice had not been given.

Dr. E. T. Wilkins, replying to Dr. Craxford, said it could not be concluded from the results given in the paper that a smokeless zone was ineffectual during smog. From Fig. 7 it would be seen that, during the smog, the area of maximum pollution did not cover the City on that occasion; but, it might well have done if the City had not been smokeless. Evidence that a smokeless zone did, in fact, remain less polluted during smog could be seen in the deep indentation in the smoke contours of Fig. 7 in the region of the open spaces of Kensington and Westminster. That this should be so is not surprising because during smog there is generally little wind or atmospheric turbulence which alone can cause pollutants to drift into a smokeless zone.

Dr. Wilkins thought that owing to the paucity of earlier information it was not possible to show whether or not changes in average air purity accompanied the establishment of the smokeless zone in the City in 1955. However, it appeared from the paper that the degree of pollution in any area depended largely on the amounts of pollutants emitted into atmosphere in that area; consequently, if smoke emissions had decreased in the City as he believed they had, there must have been a corresponding decrease in pollution.

Dr. D. D. Reid, replying, thanked Dr. Craxford and Mr. Spence for their suggestions on the relevance of the effects of ammonium sulphates and sulphur dioxide. Both these aspects of air pollution in relation to respiratory disease were being investigated.

G. B. Courtier in his reply to the discussion said that speakers had been in agreement that local authorities ought to be kept informed about potential and actual radio-active contamination in their areas. Experience in the Scientific Branch of the London County Council indicated that the assessment of contamination in food and water could only be undertaken through specialized laboratory investigations and it would not in general be feasible for Public Health personnel to carry out monitoring. However, several public analysts were now being equipped with radio-chemical apparatus, and they would be in a position to make tests supplementary to those at present undertaken by the Atomic Energy Authority's research stations and those of the responsible government departments. If there should be any abnormal happening giving rise to an appreciable degree of airborne contamination, the standard smoke filters in continuous use in many areas of the country would be a valuable aid to monitoring.

Dr. S. A. Burke (replying) said he felt that answers were necessary only to the points raised by Mr. Hayward. It was true a 12 in. stoker had been constructed for B.C.U.R.A. by Mr. Hayward's company in 1954, but the results obtained with it were most certainly not those reported in the paper. Indeed the use of this early stoker had soon been abandoned and several years of research had been necessary since then; the results in the paper were obtained with stokers of greatly modified design, which had, in fact, been constructed by B.C.U.R.A. He did not think it would be fair to report the results obtained with the first unit.

He emphasized that the latter units were of a type which was not yet commercially available; they embodied methods of control which were quite novel, and the patents on which were held by B.C.U.R.A. The new control system aimed to achieve a much greater degree of automatic operation than any chain grate stokers being marketed at present.

As regards ash disposal, Dr. Burke said that under the Public Health Acts, 1936, local authorities had a duty to remove all refuse, including ash, from domestic premises; this included blocks of flats. In Britain such flats were usually heated by sectional boilers of the type referred to in the paper, even where several blocks were grouped together.

He was well aware of the value to market gardeners of these heating boilers and stokers, but he had not mentioned it in the paper, because he did not think it was relevant. The paper concentrated on the requirements of Smoke Control Areas, which were much more difficult to satisfy than the standards set by the Clean Air Act for other parts of the country.

The Ninth Des Voeux Memorial Lecture

Clean Air, Urban Amenity and the Growth of Towns

by

Sir William Holford

D.Arch., F.R.I.B.A., M.T.P.I.

Introduction

RECENTLY, in Central Africa, I had the opportunity to visit some of the sites chosen by the original Bushmen for their encampments. I noticed that while the lip of the cave or the shelf of rock on the side of the hill gave them a strategic view over the surrounding country and its game, some of the sites also made use of fissures and chimneys in the rocks behind, through which the tell tale smoke of their own fires could be carried through the hill and dispersed some distance away.

I am not one who believes that history repeats itself; but I cannot help being struck by the way in which certain basic human requirements keep recurring through the centuries, not always in the same way or for the same reasons; and invariably calling out a new technical response from the age in which they reappear.

Last year Sir Graham Sutton gave you an exceptionally interesting address on *Meteorology and Air Pollution*.[1] He began by doubting whether we should ever " . . . entirely control the natural processes by which noxious substances emitted into the air are diffused. The real remedy ", he went on to say, " is to stop putting such substances into the atmosphere, but since, at the present time, this is a counsel of perfection, we are justified in inquiring closely into what happens to the foreign matter when it has been introduced."

In the light of the knowledge and skill then prevalent, the primitive hunters must have known as much about airflow and smoke diffusion for their own purposes as Sir Graham Sutton does for his; and the more serious reason why I have made this somewhat mischievous comparison is because the phrase " a counsel of perfection " illustrates so well the dilemma in which town builders have been placed ever since town building began. Unpolluted air must always have been desired in the building of huts, camps, castles and—eventually—cities. Homer is the first of a long line of storytellers, architects and scientists who have told us so.

Even when chimneys were out of fashion in the building of the great classical country houses of the eighteenth century, the ingenious Colen Campbell, at Mereworth in Kent, took all the flues from the fireplaces round the ribs of his central dome and out through a copper cupola at the top.

The difficulty is that while private comfort and private amenity are often available—though sometimes at great cost—public comfort or public amenity of the kind required when " men come together in cities", as Aristotle said, "to live the good life", are always subject to more imperative requirements of the community, such as its defence, or its economic subsistence.

But you have not asked me to talk about town building in the past, nor about the way in which historic towns have avoided or endured the hazards of smoke and fog and sulphur dioxide. You have asked me to talk about air pollution, in relation to town planning; and although no one concerned with the study of environment can escape the past or ignore its lessons, yet the accent is clearly on what can be done, now and in future to give back clean air to a country that is becoming ever increasingly urban and industrial. This, at least, is what I understand to have been Dr. Des Voeux's objective, sixty years and more ago; and it is the theme of the Lectures which you have instituted in his memory. I am glad that you have devoted the ninth in the series to town planning, especially as the subject of town planning, as it is now understood, is a newcomer when compared with the subject of smoke abatement. Although I can tell you nothing of scientific importance—as some of my predecessors have done—I shall try to draw some interesting parallels between our respective activities.

Town Planning: A Comprehensive and Continuous Process

Perhaps the best way to establish these parallels is to make clear some differences; and they are very great. Clean air is at any rate a finite and foreseeable objective—like winning a campaign in a war. To win a campaign does not solve a nation's problems, as we have good reason to know. But it completes one operation and provides an approach to the next one. Similarly, the elimination at source of the greater part of our air pollution by industrial and domestic waste, would still leave problems of temperature inversion, frost pockets and fog. But at least one arduous operation would have been successfully concluded, and the Society could once again—and most honourably—change its name!

Town planning has no finite objective in this sense. In its modern form it is a formal and continuous process for regulating the use of land, controlling various aspects of our physical environment and providing opportunities (and sometimes designs) for new construction and development. It is inexact as a science, and as an art, imperfect and somewhat tentative. Nevertheless it provides a method—the only one our urban and industrial society has evolved—whereby waste, friction and inconvenience in our daily movements can be progressively reduced, ever larger populations accommodated, the amenities preserved and extended, and more reasonable—if not more imaginative—settings created for our life and our work.

Along this line of progress the achievement of clean air in town and countryside would be a major victory. In this paper I hope to show that when working to a vast and many-sided programme, such as town and country planning, the only way to show results which will encourage the public—or should I say ourselves, in our public capacity—to take further steps towards the Ideal City, which from time to time we dream of but never reach, is to mark the milestones as we go along. The achievement of smokeless air would represent such a milestone; and it is still some way off. But beyond it are further milestones on the same road: how to deal with the products of the internal combustion engine (four million gallons of petrol a day are consumed in Los Angeles[2]); how to dispose of atomic wastes, as Dr. Bronowski forecast in his 1951 Lecture[3]; how to supersede cooling towers; how to cleanse our rivers.

These and many other technical problems are with us, and their complete solutions still lie ahead. They are inseparable from the problems of social waste in which town planners and urban sociologists are now deeply involved, such as traffic congestion, the uneconomic nature of the long journey to work, and the rate of obsolescence of dwellings.

It is clear that the town planner must look to the scientist and the industrial technologist to find solutions to specific technical problems. These will all make for the better physical climate and the more productive environment for which he is trying to plan. But, in return, the town planner can contribute something from what I can only call—and you must excuse the jargon—his inter-disciplinary experience. He can also suggest some of the techniques of collaboration; for the technical advances have to be carried out within the framework of economics, of law and public administration, and of social custom, which all regulate the pace of planning and of any subsequent development which results from it. And if you ask what particular interest an architect has in this process, my reply is that the architect is trained to it, even though his responsibility, as an architect, may not go beyond an individual building. The essence of his training is design—that is to say, the method by which a number of technical means are used for aesthetic ends. This is fundamentally the same process as that of the painter and sculptor; only that the means of designing buildings—and still more a housing estate or a town—are more complex and less personal than those in the fine arts. They are also more highly organized from a social point of view and need more elaborate co-ordination.

In short, the end product of the town planner's research and designs, and of the presentation of his proposals, must be visible as buildings, landscapes and roads, or as patterns of settlement and land use.

A Chart of Town Planning Activities

In so far as such a process can be systematized, town planning—in a small and highly developed country such as ours—may be said to consist of a number of general aims, which remain constant, and a number of controls, which vary from time to time and place to place, but which are necessary in a democratic society to define these aims and compare one with another. For the fact is that if any one objective is pursued on its own, it will come into conflict with the others. For this reason the supreme planning function of the Minister of Housing and Local Government, as laid down by statute, is to secure consistency and continuity in the use and development of land.

At the risk of appearing academic, I would like to summarize these aims and these controls. There is a good deal of misunderstanding of what town planning is about. To some it is just a dirty word; while others credit it with a capacity and an authority it has not got. Moreover a chart of town planning activities is the clearest way of exposing my subject, which is the relation between clean air in particular and an improved environment generally. You will notice at how many points they touch each other.

The Countryside

1. The first aim is to preserve and improve the means of natural recreation. This may seem the opposite extreme to town planning, but in fact it is a reflex; for the bigger and more urban our population becomes, the more essential it is that solitude and wildness, sparsely inhabited areas and national parks, the woods, the moors and the coastline, should not lose their natural quality. The category stops short of real desert; for it must be recognized that what natural recreation means to an urban population is a contrast of amenity, not the loss of it altogether; while, to the rural population, the national parks are much less important. The effect of drift pollution on every kind of natural amenity—on atmosphere and visibility, on animal and bird life, on hill grass and hill farming, on the whole ecology of an undeveloped area—can be easily understood, even

if a good deal of detailed research remains to be done. Smoke particles can be carried hundreds of miles, and a recognizable smoke pall at least thirty; while the average life of a sulphur dioxide molecule has been estimated at two to three days. As, apart from natural air turbulence, no economically practicable defence can be put up by remote districts, the only remedy in this case is the absence of pollutants—the " counsel of perfection " referred to by Sir Graham Sutton. Even green belts must otherwise be tinged with grey.

2. The next aim is to reserve the most suitable remaining land that is still undeveloped, for agriculture, forestry and the rural occupations and industries associated with them. This means also the improvement of housing, transport, social services and public utilities for those who work on the land. The effects of air pollution here are much the same as for the more remote country districts; but of course they are strongly accentuated in the neighbourhood of industrial towns, and the economic and social consequences are more serious. Hill farmland, in particular, which normally has a higher rainfall than the average for the country as a whole, already runs the risk of soil deterioration through erosion and leaching, and this is made much more serious if the air is polluted and if impurities are also present in raindrops and other forms of condensation. Foresters and farmers then complain of retarded tree and crop growth, of poor pastures, deterioration of stock and reduced milk yields. Dr. Alice Garnett of the University of Sheffield, discussing the geographical factors of air pollution,[4] has demonstrated the relationship of rainfall acidity to sulphur dioxide, with particular reference to the Don Valley. And anyone who remembers the disastrous effect on the prize livestock exhibited at Smithfield during the London fog of December 1952, will appreciate how vulnerable the animal world is to atmospheric pollution.

Housing

3. The next aim of town planning is to facilitate housing, in all its forms, and particularly in regard to its location, its quantity, its quality, and its social arrangement. There is always a housing shortage. It is either general—as at the end of the last war—or it affects particular areas, types or income groups, or it is accentuated by slum clearance and what the Americans call " urban renewal ". With every form of housing, atmospheric pollution is intimately connected; and in most of our towns housing is not only the chief source of smoke, but also constitutes the reception area most adversely affected by it.

Up to a point, the higher the density of the housing, the greater the density of the smoke. This was certainly true of the so-called 'by-law' streets in our industrial towns, where dwellings at 36 or more to the acre were designed to cast 85 per cent of their domestic fuel into the air or onto the chimney flues. It was also true of central London when it was on the average three floors high, and even more so in the nineteenth century when it became five floors high; for there were then more flues to the square mile. The steel frame and the electric lift broke the height barrier. Now that blocks of flats are being constructed 9, 11, 14, and 16 floors high, it is obviously becoming uneconomic, from a building point of view alone, to carry flues from each dwelling to the top of the block. The truth of the old saying: " where danger is salvation also lies ", is demonstrated by the fact that such flats are now being equipped more and more with direct and off-peak electric heating, using both radiation and thermal storage[5].

Yet the hard core of the domestic smoke problem remains. There are still large concentrations of obsolete equipment in otherwise habitable houses, and the Treasury imposes a heavy Purchase Tax on gas and electrical heating appliances—including domestic storage heaters. Even new blocks of dwellings with flat roofs seldom possess means of carrying chimney gases from central furnaces high enough into the air to escape lee eddies and down draught. Housing estates are still located in frost pockets and in areas subject to frequent temperature inversion and consequent fogs. (This is contrary to the advice which a meteorologist or a micro-climatologist would give the housing or the planning authority, but such advice is either considered irrelevant or is outweighed by other considerations such as land values and availability, or nearness to a bus route or railway station.) As the town planner can only influence present and future development, his best course is to support in every possible way the combined operations envisaged by the Clean Air Act, and pay particular attention to the characteristics of new land for housing and of the type of dwelling and of equipment proposed to be installed there. (In this connection I shall refer later on to the importance of the decisions taken on the form in which a particular town is allowed to grow.)

Public Services and Utilities

4 and 5. Next in order among the aims of town planning are those intended to facilitate transport and communication, and to provide for the public utilities such as water and drainage. The effect of fog on all forms of traffic, except underground traffic, is patent; but it is not precisely calculable in terms of cost. On aviation, however, it is decisive. And it is a pity that Gatwick, newly opened as an alternate to London Airport, cannot produce a truly alternate fog pattern. But little seems to be known, at present, of the other side of the picture—the effect on air pollution of the combustion of diesel oil and petroleum in millions of vehicles on the roads, and the annual discharge of some 25 million tons of carbon monoxide. That there is some injury to health is obvious from their effects, under conditions of relatively stable air in the middle of towns, on those who are irritated by exhaust fumes and are even allergic to them. But the extent of the damage, in the absence of other pollutants, does not appear to have been calculated, except in very special cases. It would also be interesting to know whether it predisposes certain people—as heavy cigarette smoking is said to do—to carcinoma of the lung.

Here again the only town planning remedy lies in trying to reduce the worst concentrations of traffic—particularly in streets and semi-enclosed places where natural ventilation and air turbulence is below the average. Simultaneously a great deal could be done by adopting Sir Hugh Beaver's suggestion that toxic motor exhausts should be dealt with in the same way as the scheduled processes: i.e. by continual informed challenge[6]. (Under the Town Planning Acts the problem of advertisements is approached in much the same way.)

6. The next objective is to make provision for the generation and distribution of energy. This aim, in so far as it means gas and electricity, is in line with the objects of this Society. It is most completely so where atomic fuel is used, and normal air pollution problems are absent; such as smoke, grit, ash disposal, SO_2 and other toxic gases—for it now seems clear that there is not likely to be another accident such as occurred at Windscale.[7] As one goes down the scale of generation, however, the heat, light and power processes become less susceptible to control, either by town planning or under the Clean Air Act. While power stations and Gas and Coke Works are scheduled under the Alkali Act, electricity generating plants which burn less than 500 tons a day, for industrial purposes, are not.

From the town planner's point of view the public is more concerned over the distribution of electricity than over the loss of amenity caused by the incomplete combustion of solid fuel—probably because the former is more visible and makes an easier scapegoat. Yet the latter is thoroughly wasteful as well as damaging, whereas the former is an efficient means of distributing energy and as it becomes even more efficient will achieve a greater distinction of design and greater simplicity.

It is a curious feature of an industrial country such as ours, that while the approach to both roads and railways has been one of continually improving the engineering design itself by public criticism, competition and imaginative skill—so that names like Macadam and Telford, Stephenson and Brunel, have become household words—the distribution of electricity, in which we lead the world, is regarded with almost universal prejudice as a necessary horror which should be put underground and out of sight, like sewage. I sometimes wonder whether the next century will see a movement for the preservation of old power stations and pylons, as there is now for old railways and for Cornish Engine Houses.

One further point about power station chimneys is perhaps worth making: it is that their height should no longer be governed by an arbitrary rule of two-and-a-half times the height of the boiler house, but by a calculation in each case which would take account of topography and airflow, the maximum concentration of smoke at ground level (which varies inversely with the height of the chimney), and the temperature of the stack gases before diffusion.

Despite all the technical precautions that can be taken it is sensible to secure a safe location for coal and oil-fired generating stations and for gas works: i.e. downwind from at least the more concentrated centres of population.

Industry and Commerce

7 and 8. Next on the list are industry and commerce—our major sources of livelihood—whose zones of activity are not only important in the campaign for clean air, but also the most controversial in town planning theory. Early legislation, with an eye on the black legacy of the nineteenth century industrial towns, naturally segregated special or noxious processes from general industry, and both from residential use. In detailed layouts planners went even further, and distinguished between " clean " and " dirty " factories.

When I prepared the layout for the Team Valley Trading Estate at Gateshead in 1936, I allocated an area at the windward and more rural end of the estate for firms who might wish to manufacture under specially hygienic conditions: e.g. patent foods, cartons, photographic material etc. Meanwhile, Special (now known as Development) Areas legislation, the Barlow Report and the Distribution of Industry Act of 1945, all helped to induce industry to move from the big cities—and especially from London and the south-eastern region—in the interests of a more balanced employment structure. The wartime plans for the County of London[8] and Greater London[9] carried industrial segregation policy a stage further, and tackled the problem of " non-conforming " industries and backyard factories in residential areas; although the Greater London Plan made an attempt to except what it called " service industries ", defining them according to their domestic character, innocuous processes, and the small numbers employed. Finally, the Town and Country Planning Act of 1947 established the Use Classes Order and the need for planning permission to change land or premises from one use class to another.[10]

No sooner had this segregating mechanism been set up than it had to be overhauled. In the series of post-war economic crises (which are still with us) capital expenditure for new building and war-damage replacement, as well as for re-location and re-grouping into tidy use zones, could not be supplied to the extent desired. In the second place, office employment grew very fast in relation to factory employment, and " employment " rather than " industry " became the principal factor in the town planner's struggle for a less congested pattern of population and land use. And in the third place there was a growing number of reasons why factories were becoming cleaner and more neighbourly. There were, for example, improvements in fuel techniques, a reduction in night shifts, and an increase in the so-called " footloose " consumer industries, using electric power and a high proportion of female labour, and capable of setting up almost anywhere in the country where this was available.

All these changes made general industrial segregation either less practicable or less important. At the same time the exceptions—including noxious trades and processes with nuisance value in a residential community—were being more clearly identified.

Modern town planning practice, therefore, while it still favours for many reasons the principle of grouping together similar industrial uses, is now much more selective in its definitions. It admits the advantages of having certain categories of employment—especially commercial and service industry[11]—in or near residential zones, while giving special attention to dirty, noisy and smelly trades, and to works scheduled under the Alkali Act. It is worth noting that certain industries not likely to be included as scheduled processes under the Clean Air Act may still be dealt with by local authorities under the Town Planning and the Public Health Acts.

Social Organization

9 and 10. Lastly, town planning seeks to assist all forms of social organization. This is a town's main function; and it includes educational and health services, the means of debate and assembly, universities and cultural institutions, opera houses, concert halls, museums and galleries, the seats of local or central government, churches, monuments and shrines.

Air pollution directly affects the health services—and the veterinary ones also—but in the operation of the social services its role is, naturally, indirect. But insofar as these activities and services are represented by buildings, then the discharge in Great Britain during a year (in this case 1954) of two million tons of smoke, eight hundred thousand tons of grit, and over five million tons of sulphur dioxide, is a matter of very serious concern.[12] For these buildings include many of our historic structures, buildings of social and architectural interest, cathedrals and churches, sculpture and monuments, whose economic life is much longer than that of normal houses, offices or factories, and whose " restoration " has to be faced. Appeals for such restorations already known to me at the present time amount to a total sum of nearly fifty million pounds; and there must be hundreds of which I have not heard. Dilapidation is not all due to atmospheric pollution, but a very high proportion of it is; and it ranges from valuable and irreplaceable items such as the Grinling Gibbons sculpture on the walls of St. Paul's Cathedral in the City of London, to the small box hedges which will no longer grow at Aston Hall, in Birmingham.[13] Under the Town and Country Planning Act, lists are slowly being completed of all the buildings of " special architectural and historic interest " in England and Wales, and it is likely to number over 100,000. Under the Historic Buildings Act, Parliament votes annually a sum of upwards of £250,000 to help their owners to maintain some of the most outstanding examples. As an architect and as a member of the Historic Buildings Council for England, I realize how much farther this small sum would go if the main source of building dilapidation could be eliminated or even reduced. For this, as well as many other reasons, therefore, town planners will be anxious to see the programme fulfilled whereby 400,000 to 500,000 urban acres a year are brought progressively within the boundaries of Smoke Control Areas.[6]

These ten positive aims of town planning, which I have just summarized, add up to the sum of urban development, but they do not make towns. A town must have some unity and character of its own, differentiating it from other towns, and derived partly from its situation, partly from its social form and characteristics, and partly from the economic basis of its life. The shell of the society which the town represents has either grown slowly over the centuries, or is custom built in the first place—whether as *Villeneuves* in the reign of Edward I, or as *New Towns* in the reign of George VI. In either case the growing points of development and redevelopment at any period will substantially change the form of the town—or the city or the village, as the case may be. They may also alter the town's response to the changing environment of which it forms a part. Knowledge of these responses, and skill in the kind of civic design which will adapt the town to its environment—physical, social and economic—is the real essence of town planning. In relation to the omnipresent factor of air pollution, it is, therefore, worth looking at one example of the town, not as an assembly of parts, but as a complete organism.

Satellite Growth Versus Spread

In the remaining period during which air pollution by domestic and industrial concerns is still very much a problem—although a gradually diminishing one—some thought might be given to the ways in which a town spreads.

A good illustration is afforded by a comparison of the two university cities, Oxford and Cambridge. Both are free of drift pollution from nearby industrial districts. Both are prone to high humidities. It is true that Oxford, like London, with its generally concave topography is more subject than Cambridge to the downward creep of cold air from the hill slopes, and that the katabatic breezes lead, during anti-cyclonic weather, to temperature inversions and valley fog. But there can be very little doubt that air pollution not only contributes to the fog condition but prolongs it; and in both cities the pollution is mainly of local origin.

Oxford has appealed for more than two million pounds to assist the repair of decayed stonework. Cambridge has invited contributions and grants for the normal restoration of individual buildings and groups, but for nothing of this order of magnitude. Oxford grew in the nineteenth century from 12,000 to nearly 50,000 inhabitants; Cambridge from 15,000 to 38,000.

It was during this period that the individual coal fire became entrenched, not only in the closely packed terrace houses but in the college quadrangles as well; and it is only since the Second World War that it has begun to diminish in numbers and effect, and after 1921 both cities experienced an abnormal growth in houses and population. The continuously built-up area of Oxford now contains a population of about 120,000 and Cambridge about 104,000.

In a most interesting study called *Smoke Over Oxford*,[14] Dr. Beckinsale and Mr. Combey (the Chief Public Health Inspector) mention the four sources of pollution there as:—

(*a*) domestic: particularly the nineteenth century terrace houses;
(*b*) collegiate: also a dense form of residential use;
(*c*) manufacturing industry: including the older factories and works west of the centre and near the railway, and the newer and " cleaner " industry at Cowley; and—
(*d*) public utilities, such as gas and electricity generation and the railway yards.

They also point to recent reductions, due to diesel-electric locomotives, improved boiler equipment, a new housing estate established initially as a smokeless zone, and increased use of electricity. They quote one college which burnt two hundred and thirty five tons of solid fuel in 1929, and thirty years later is burning less than twenty. But 85 per cent of that solid fuel must have been wasted, and through this very waste, millions of pounds worth of damage was done—some of it irremediable.

The comparative atmospheric improvement in both university cities in very recent years is impressive. But in this, as in other matters, town planning has to deal with the legacies of the past as well as with extensions into the future. There are many contributory reasons for the plight of Oxford's historic buildings besides the climatic ones. There is the very general use of pervious limestones, the town's higher industrial capacity on the transport lines between London and the Midlands, the sheer neglect of building economics and management (characteristic of university societies until quite recent times), and inversely the sheer beauty and associative importance of the buildings themselves. But one factor revealed by the studies of air pollution in both centres—and particularly so in the case of Oxford—is the increase of extent and of density in the continuously built-up area. And here Oxford and Cambridge policies diverge.

To the best of my knowledge, Cambridge is the only town in England (I except from this list the two garden cities, Letchworth and Welwyn, and the County of London), which has deliberately used its powers under the Town and Country Planning and the Distribution of Industry Acts, to limit its urban spread.[15] Cambridge, city and shire, decided in their Development Plan, and it was approved by the Minister, that a town twice as big would not have twice the advantages of a Cambridge roughly its present size. On the contrary a great number of amenities would be lost. Residential and industrial expansion should, therefore, be encouraged in surrounding villages or satellite centres, and (with certain exceptions and " infillings ") discouraged in Cambridge itself, which would gradually be modernized by redevelopment rather than by peripheral extension.

The importance of this decision in reducing some of the problems of atmospheric pollution will readily be understood.

In Oxford, on the other hand, if my interpretation of the arguments supporting the city's claim to boundary extensions is correct, the policy is to accept the inter-war expansion of the built-up area as inevitable, and to be repeated. The corollary is that new Council estates, such as Blackbird Leys, will have to be not only declared, but actually built as smokeless zones; if the existing problems of pollution in Oxford are not to be worsened. From the point of view of general progress towards clear air in housing estates, this will, of course, be a step forward, and it serves to illustrate another example of the way in which smoke abatement and town planning can provide alternative policies.

My own view remains, however, that their activities should be complementary.

Conclusion

In this brief review I have outlined the town building process, emphasizing the positive features of urban development and referring them to one item in particular in the list of checks and balances which I have called *Controls*—namely, Clean Air.

There are, of course, many other controls on the regulatory side of the town planning process. There are other anti-pollution controls affecting water and industrial effluents, surface mineral workings and noise. There are regulations governing advertisements, road signs and petrol filling stations. There are building byelaws and planning restrictions that limit use, height and density. All these attempt to regulate development in the interests of public amenity, safety or health.

There is a second set of controls which derives from publicly accepted preservation policy, although the means are partly official and partly dependent on informed public opinion.

It includes nature conservancy, access to commons, footpaths and mountains, the preservation of trees and of ancient monuments and historic buildings.

There are also economic restrictions on every form of development, which are often decisive in matters of amenity and preservation. The Treasury control normally takes the form of saying " We cannot afford it ", to which public opinion often replies " We cannot afford *not* to do it ". And the result is one of those inevitable compromises of which all regulatory town planning consists.

But there is also a fourth set of controls where compromise in this sense does not figure, and that is design itself. For design is also a control, by means of selection and imagination, over the raw materials of land and building development. Site and cost and building programme all establish conditions within whose limits the designer has to work; but as design is essentially a creative act—an expression of personality—any further compromise or indecisiveness after the programme has been established is a defect. And this applies as clearly to the design of a new town as it does to the design of a power station or of a street lighting column.

I have always felt strongly that the control of air pollution is one of the most important of these town planning controls. Its importance is social, economic and preservationist; and for these reasons it should be a factor in design. And it too seldom is.

On the other hand, I want to end on a plea for simplification. I have tried to show not only the complex nature of the combined operation we call town planning, but also the conflicts that are bound to exist between a number of legitimate interests, all desirable and even necessary in themselves. Only when the final aim is very clear, or the emergency overriding, are these forces and pressures resolved. It is just conceivable that one could design a perfect heating system, but it is inconceivable that anyone could design a perfect town, this side of the pearly gates, at any rate. Therefore the identification of objectives becomes essential; and so does the training of staff to exercise in an intelligent way more than one control. Local authorities are largely responsible for the supervision of air pollution, and almost entirely for town planning—both under the same responsible Minister. Sir Hugh Beaver's Committee referred to the shortage of staff as one of the main stumbling blocks in the way of the administration of an effective clean air policy.

I may not be popular with town planning officers and their committees in pointing the obvious moral. But if the planning staff cannot actually supplement the Health Inspectorate in administering this control, it seems clear that liaison between them should be as close and as labour-saving as possible.

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Wynn, G. A., (PHI), *Holywell*

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Young, J. J., *Ford Motor Co. Ltd.*
Yule, Dr. J., (MOH), *Stockport*

Z

Zammit, Ald. J., *Llanelly*

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PROCEEDINGS

OF THE

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LONDON
OCTOBER 1959

NATIONAL SOCIETY FOR
CLEAN AIR
GREAT BRITAIN

THIS volume contains the 78 Papers, from 17 countries, that were presented, in printed form, at the International Clean Air Conference in London in October, 1959. Grouped according to subject, the Papers in each session were reviewed by a Rapporteur, and these reviews, together with the general discussions that followed, are also recorded in the book.

The Conference (with a Clean Air Exhibition) was organized by the National Society for Clean Air to celebrate the Diamond Jubilee of its foundation. It was honoured by receiving the Patronage of H.R.H. the Duke of Edinburgh.

The number of Papers, the varied aspects of the problems of air pollution that they cover, and the number of different countries represented by the contributors, make this the widest and most international survey of the problem ever to be published.

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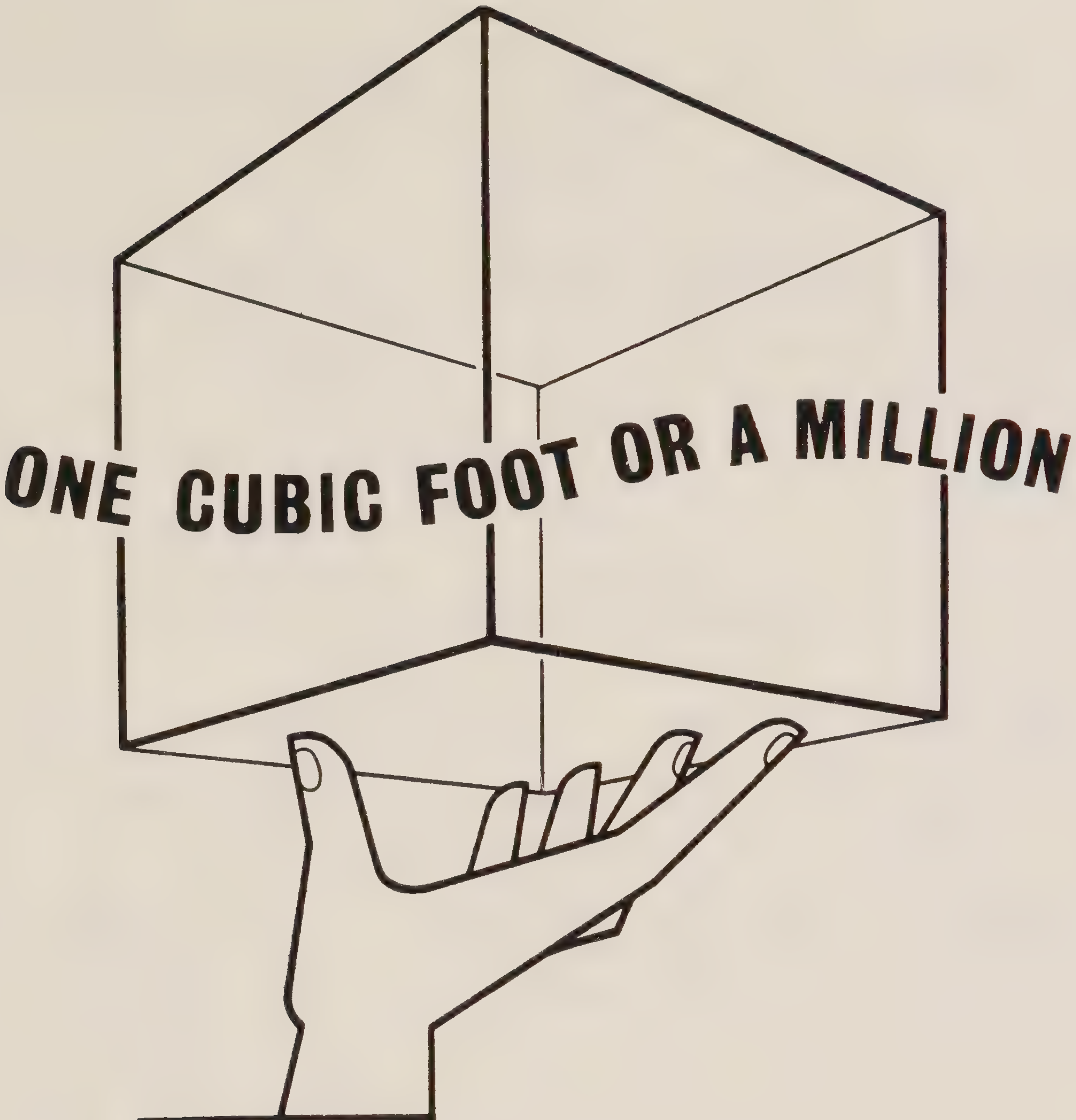

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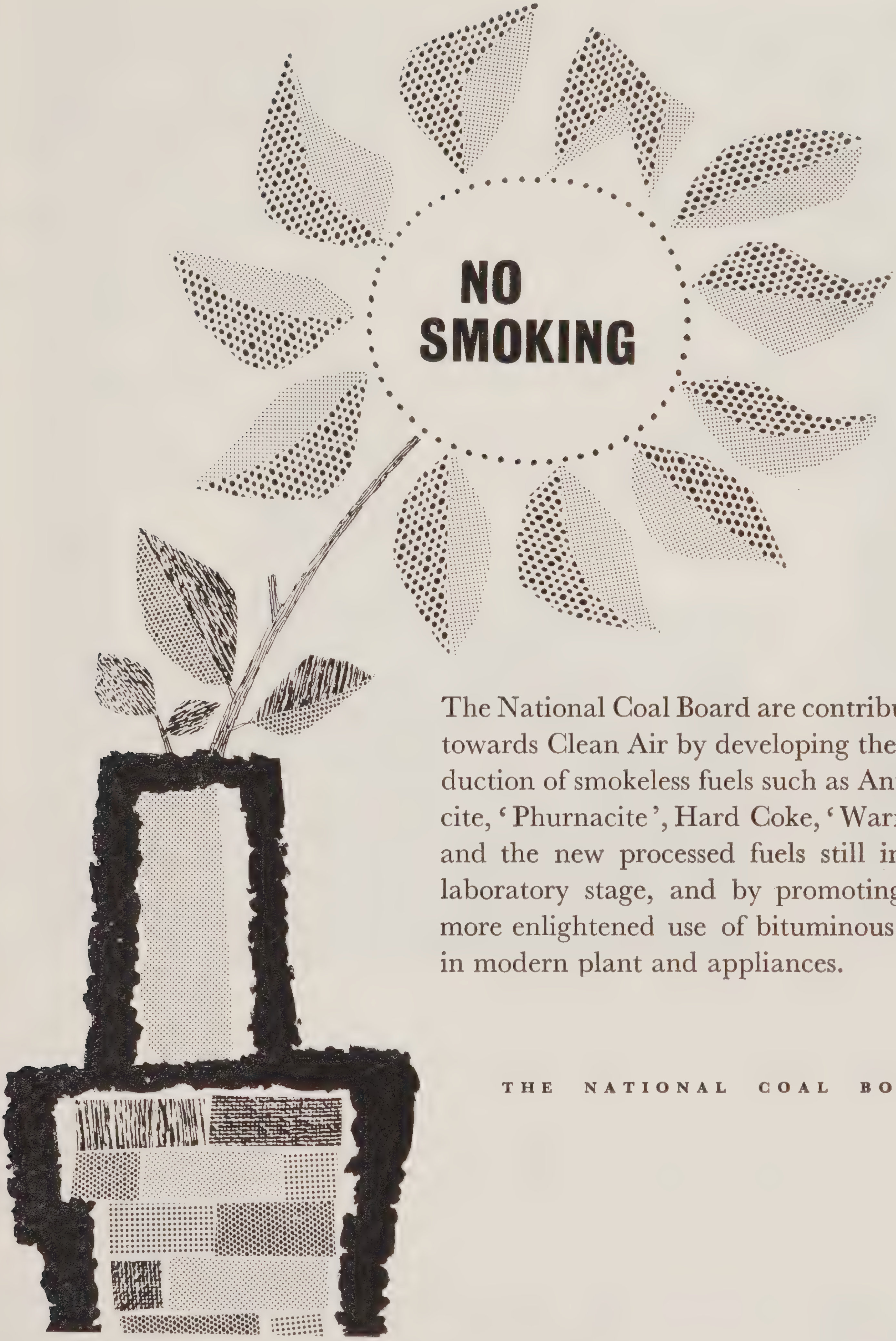

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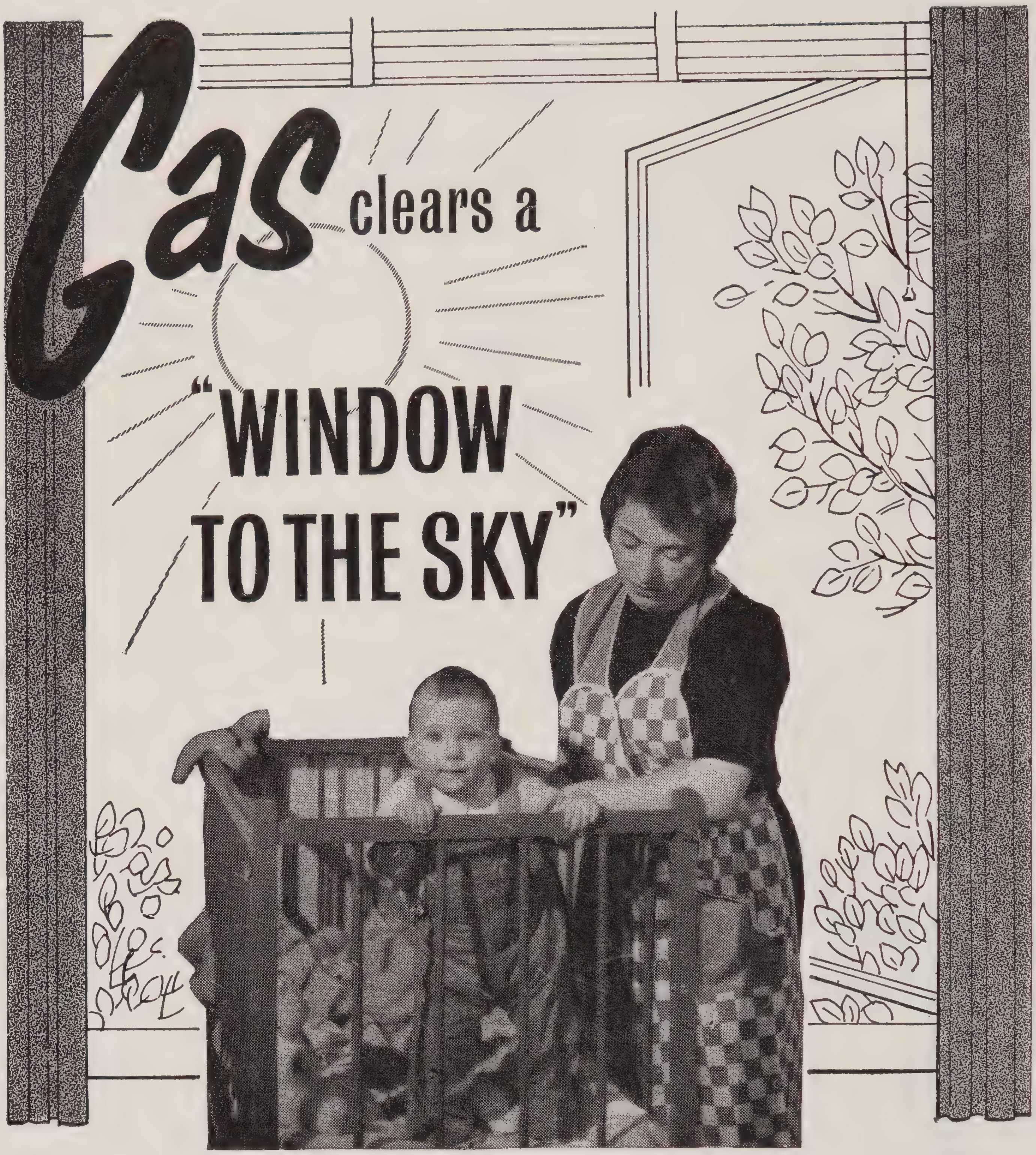

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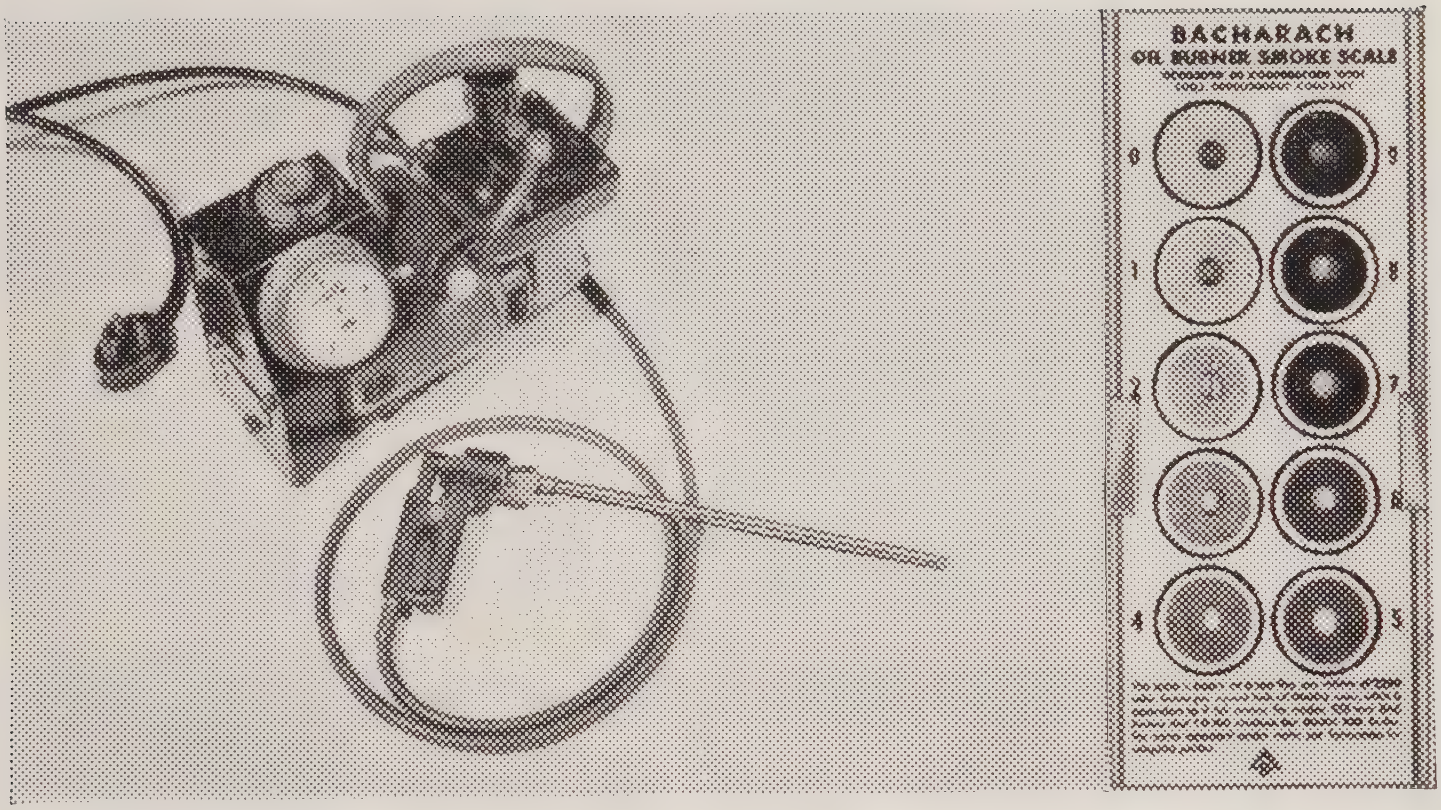

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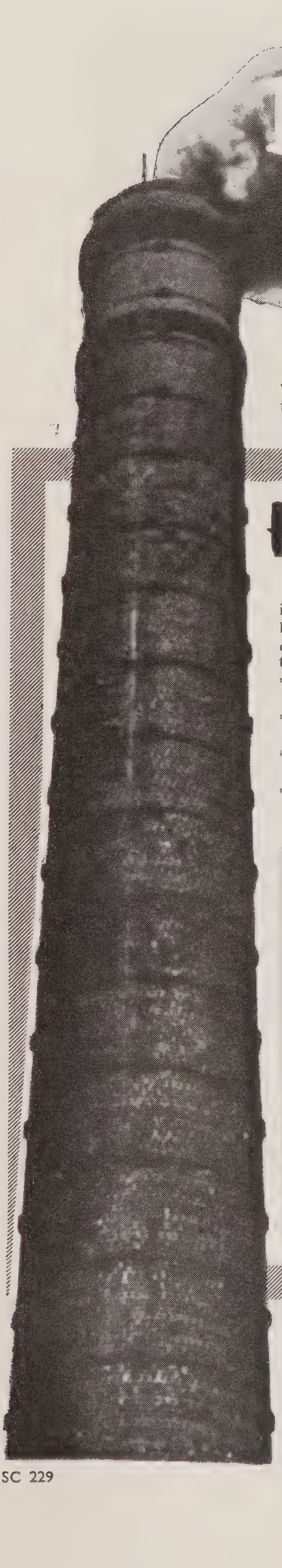

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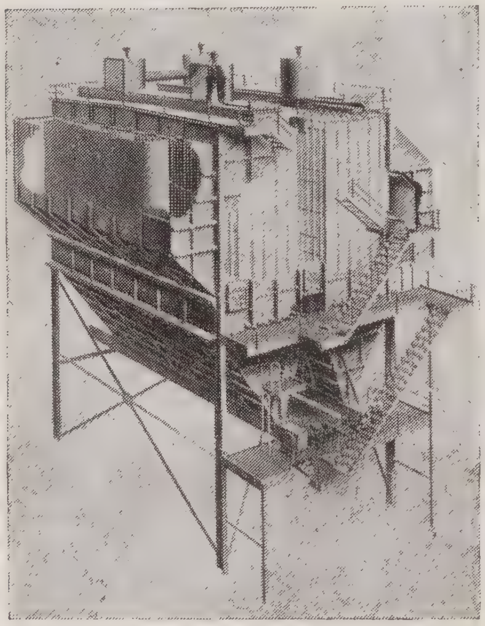

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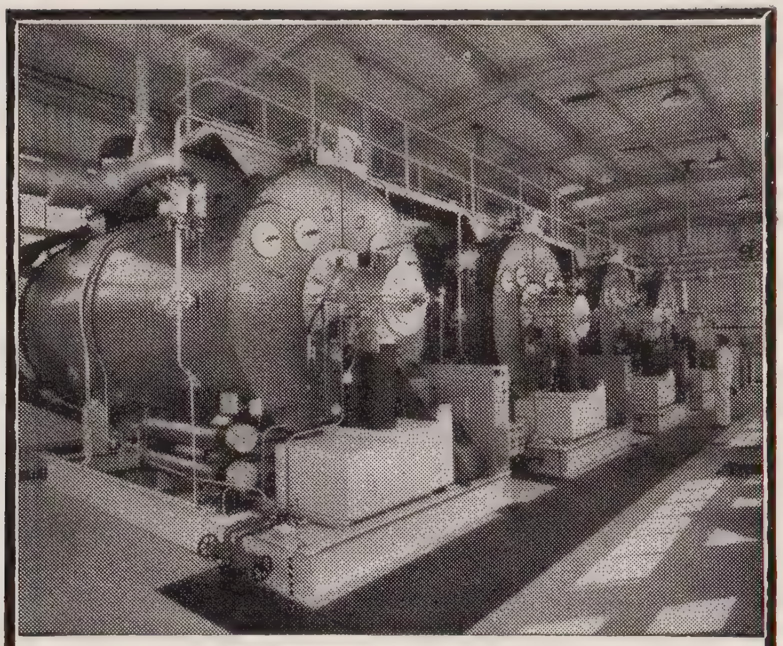

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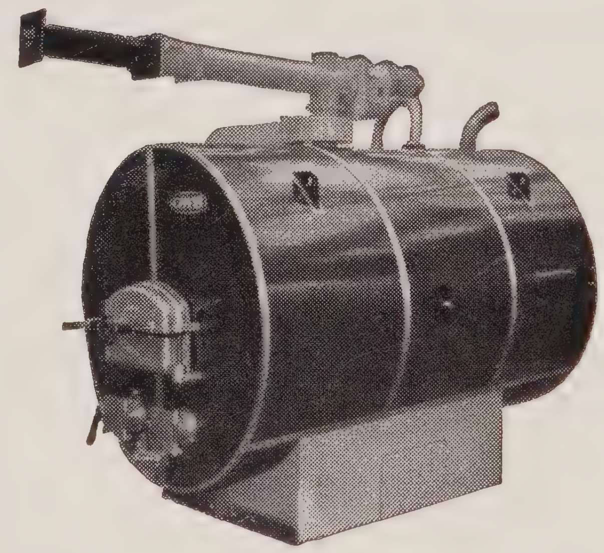

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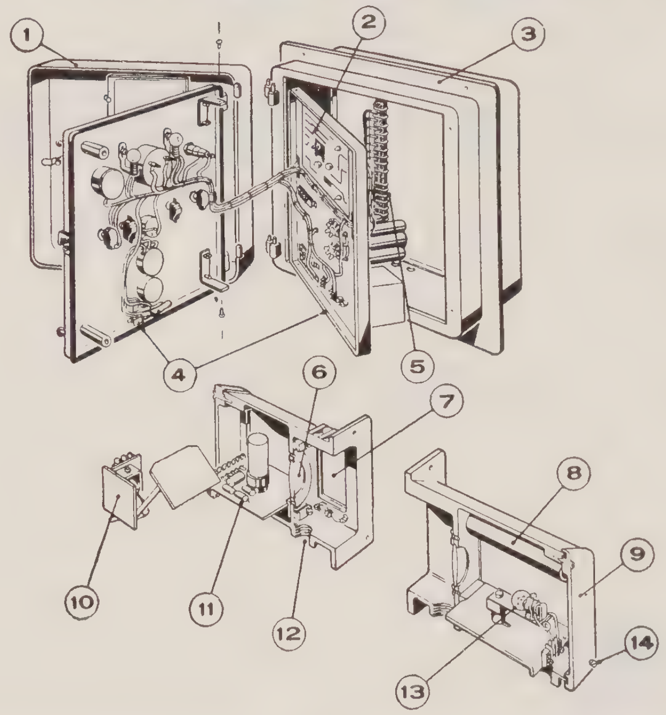

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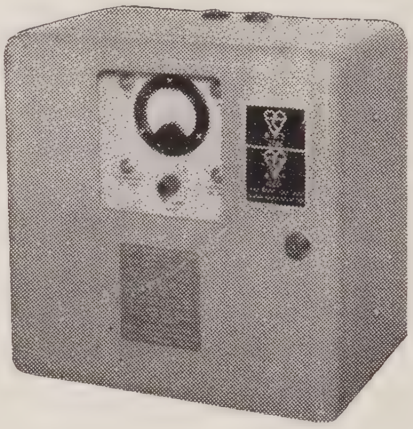

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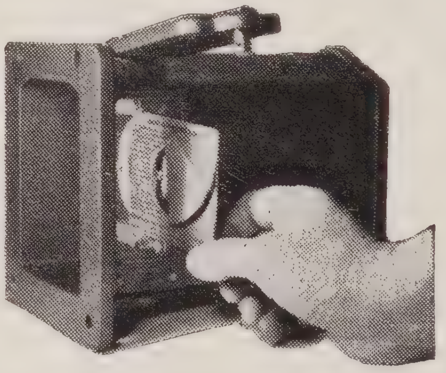

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CONTENTS

Page

Message from H.R.H. the Duke of Edinburgh, K.G., K.T. 13

Introduction 14

The Opening Address, by Sir Graham Sutton, C.B.E., F.R.S. 15

Papers from Session II—National Air Pollution Problems, Legislation, Education, etc.

1. **P. D. Coates:** Air Pollution Legislation and Administration in Great Britain 18
2. **C. Brosset, H. Ronge and R. Spaak:** A Planned Investigation of Air Pollution in Gothenburg, Sweden 20
3. **J. H. Carter:** The Successful Anti-Smoke Programme of St. Louis, U.S.A. 21
4. **F. E. Dawson:** Legislation and Administration in Small States (Eire) 23
5. **Federal Ministry of Labour, Germany:** The Present Degree of Air Pollution and the Relevant Laws and Regulations in Force in the Federal Republic of Germany 25
6. **K. Guthmann:** Air Pollution Problems in the Federal Republic of West Germany 27
7. **E. C. Halliday:** The Development of Public Opinion on Air Pollution in South Africa 29
8. **Institute of Public Health, Japan:** Public Opinion and Education in Japan 31
9. **Institute of Public Health, Japan:** Legislation in Japan 32
10. **M. Katz:** The Control of Air Pollution in Canada 34
11. **E. Leclerc:** Some Activities in Belgium in the Field of Atmospheric Pollution during the Last Five Years 38
12. **W. Lindberg:** Atmospheric Pollution Problems in Norway 40
13. **A. Marsh:** Public Opinion and Education for Clean Air in the United Kingdom 42
14. **T. Müller:** Investigation on Air Pollution in Basle, 1957–1959 (Switzerland) 44
15. **J. Polacek:** Clean Air in Czechoslovakia and Means for Improvement of Today's Conditions ... 45
16. **Y. Queret:** The French Association for the Prevention of Air Pollution 47
17. **O. Schmidt:** Parliamentary Initiative for the Prevention of Air Pollution in Germany 48
18. **L. Schreibeis:** Progress and the Future in Air Pollution in Allegheny County, U.S.A. 50
19. **K. Spurny and E. Lochmanova:** Air Pollution Problems in Czechoslovakia 55
20. **F. Tetzlaff and R. C. Graber:** Air Pollution Legislation and Administration in the United States 58

Papers from Session III—Technical

21. **G. H. Daniel:** The Growth in World Fuel Consumption and its Threat to Clean Air (Great Britain) 60
22. **J. Böhm:** Fly-ash Collection in Plant using Second-rate Fuel (Czechoslovakia) 63
23. **J. Bronowski:** The Development of New Smokeless Fuels (Great Britain) 66
24. **R. L. Cooper:** The Coking Industry: its Problems and its Contribution to Clean Air (Great Britain) 72
25. **R. Delbruyere:** A Commended Solution to the Problem of Air Pollution (Belgium) 74
26. **S. N. Duguid:** Education as an Aid to Industrial Smoke Elimination (Great Britain) 76
27. **K. Guthmann:** Removal of Dust from Brown Fumes in Oxygen-blowing Steelworks (West Germany) 79
28. **K. Guthmann:** Technical Removal of Dust as Dealt with by the European Coal and Steel Community (West Germany) 82
29. **R. F. Hayman:** Gas in Industry (Great Britain) 83
30. **J. W. Jacquest:** The Problem of Air Pollution by Diesel Road Vehicles (Great Britain) ... 85
31. **Kingsley Kay:** Environmental Arsenic Contamination and Control in Smelting Operations (Canada) 86
32. **H. Kettner:** Cheaper Cleaning Equipment for Air Pollution Control (West Germany) 91
33. **P. Lasserre:** The Problem of Collecting Dust and Gaseous Moisture at Emission Points in Relation to Air Pollution (France) 93
34. **B. Lees:** The Elimination of Acidic Smuts (Great Britain) 99
35. **R. Lessing:** Sulphur in the Air (Great Britain) 102
36. **C. Paleari and F. Renzanigo:** Diesel-oil Combustion Products (Italy) 106
37. **P. Riello:** Perfect Combustion, Essential Condition for Reducing Air Pollution (Italy) 110
38. **G. Underwood, D. Watson, S. G. McConnell and M. W. Thring:** Fundamentals of Smoke Emission from Low Temperature Furnaces (Great Britain) 115
39. **S. Weinberg and W. Randall:** Coal and Modern Equipment in Relation to Economy and Clean Air (Great Britain) 117

Papers from Session IV—Observations, Investigations and Measurement of Air Pollution

40. **H. Berge:** International Problems Relating to the Control, Inspection and the Assessment of Air Pollution (West Germany) 120
41. **Dr. Besson and J. Pelletier:** Atmospheric Pollution in the Paris Area (France) 122
42. **W. G. Cummings and M. W. Redfearn:** The Measurement of Sulphur Dioxide in the Atmosphere Power near Stations (Great Britain) 130

Page

43. **A. Giovanardi, E. Grosso and E. de Fraja Frangipane:** Researches on the Atmospheric Pollution of the City of Milan (Italy) ... 133
44. **D. H. Grindell:** Monitoring Flue Dust Surface Area (Great Britain) ... 135
45. **E. C. Halliday:** Research on Air Pollution in South Africa ... 137
46. **H. O. Hettche:** Contributions to the " Smog " Problem (West Germany) ... 139
47. **Institute of Public Health, Japan:** Research and Investigation in Japan ... 142
48. **K. R. Johnson:** The Durban Cleaner Air Campaign (South Africa) ... 143
49. **M. Katz:** The Standardization of Methods of Sampling and Analysis (Canada) ... 147
50. **H. Kirste:** Need for Standardized Methods in Air Pollution Surveys (West Germany) ... 153
51. **H. Kirste:** Dust Measurements to Determine the Sources of Emissions Damaging Crops (West Germany) ... 154
52. **D. H. Lucas:** The Calculation of Sulphur Dioxide and Smoke Concentration from Domestic Sources in Cities (Great Britain) ... 157
53. **B. Maczewski-Rowinski:** Dust Abatement by Means of a Siren (Poland) ... 160
54. **B. Paccagnella:** The Investigation of Air Pollution in Padua during the Years 1955–1958 (Italy) 167
55. **F. L. Petrilli:** Air Pollution in the City of Genoa (Italy) ... 172
56. **V. A. Riasanov:** New Data on Maximum Allowable Concentration of Pollutants in the Air in the U.S.S.R. ... 175
57. **K. Schwarz, T. Gilbert and E. Ratzki:** Research into Air Pollution in the City of Essen (West Germany) ... 177
58. **K. Spurny, M. Polydorova and J. Pixova:** Determination of Particle Sizes in Industrial Aerosols of the City Air (Czechoslovakia) ... 181

Papers from Session V—Research and International Co-operation

59. **J. O. Buxell:** Some Conclusions on the Extent and Possibilities of Co-operation Research in Europe on Air Contaminants (World Health Organization) ... 185
60. **L. W. Andrew:** The Emission of Oxides of Sulphur from Domestic Appliances (Great Britain) 187
61. **M. Clifton, D. Kerridge, J. Pemberton, W. Moulds, and J. K. Donoghue:** Morbidity and Mortality from Bronchitis in Sheffield in Four Periods of Severe Air Pollution (Great Britain) 189
62. **Ellis F. Darley:** Research on Damage to Vegetation from Air Pollution at the University of California (U.S.A.) ... 193
63. **R. Dickinson and D. E. Kimber:** An Electro-Precipitator for the Assessment of Domestic Smoke (Great Britain) ... 194
64. **R. Dickinson and D. E. Kimber:** Some Measurements of the Smoke Emission from Domestic Appliances (Great Britain) ... 197
65. **R. Harth and W. Seidl:** Documentation of Air Pollution requires International Co-operation (West Germany) ... 200
66. **H. Heiman and A. C. Stern:** Current Status of Air Pollution Research in the United States ... 201
67. **P. C. G. Isaac:** Some Thoughts on International Co-operation in Air Pollution Research (Great Britain) ... 203
68. **W. Kelm:** Steps Taken by Local Authorities in the Federal Republic of Germany towards Combating Air Pollution ... 204
69. **K. Lenhart and Dipl.-Ing. Thieme:** Problems of Smoke Emission of Coal-fired Single Stoves (West Germany) ... 206
70. **P. J. Meade:** Inversions and Air Pollution (Great Britain) ... 207
71. **Y. Nose:** Effects of Exposure to Air Pollution on Community Health (Japan) ... 209
72. **F. L. Petrilli:** Observations on the Relations between Air Pollution and Public Health (Italy) 212
73. **A. E Reif:** Carcinogenesis by Atmospheric Pollution (U.S.A.) ... 214
74. **N. A. Renzetti and George J. Doyle:** Photochemical Aerosol Formation in Sulphur Dioxide-Hydrocarbon Systems (U.S.A.) ... 216
75. **R. S. Scorer:** The Photography of Air Pollution (Great Britain) ... 228
76. **G. Spurr:** The Penetration of Inversions by Hot Plumes (Great Britain) ... 234
77. **R. E. Waller and B. T. Commins:** Air Pollution in the City of London (Great Britain) ... 236
78. **E. F. Wolf, H. L. von Hohenleiten and M. B. Gordon:** The Use of Transparent Scale Models in the Design of Dust Collector and Gas Duct Systems for Coal-burning Electric Generating Stations (U.S.A.) ... 239

Sessional Reviews by Rapporteurs, with Discussions and Authors' Replies:—

Session II (National Air Pollution Problems, &c.) ... 243
Session III (Technical) ... 250
Session IV (Observations, Investigations and Measurement) ... 256
Session V (Research and International Co-operation) ... 262

Session VI—Final Reviews, Discussion and Replies ... 270

Indexes to Authors, Speakers, and Subjects ... 280

Index to Advertisers ... 284

BUCKINGHAM PALACE

An industrial society has many advantages but one of the disadvantages is dirt. The water and the air is full of it and this pollution kills fish and vegetation, covers the countryside with grime, turns buildings black and starts them crumbling, and attacks our lungs sometimes with fatal results.

The problem of pollution of the air is common to all industrial centres anywhere in the World and it is therefore most encouraging that so many delegates from overseas have come to take part in this Conference on Clean Air.

As Patron of the Conference I offer a sincere welcome to all the delegates and extend my best wishes for the success of the discussions and for a happy and enjoyable experience.

I cannot imagine a more suitable way for the National Society for Clean Air to celebrate its Diamond Jubilee and I am sure that the discussions at this Conference will go a long way to solving some of the acute problems of the pollution of the air.

Philip

October, 1959.

quantitative was known about the way in which smoke spreads from sources near the ground. Richardson had made some heroic and significant observations with data obtained from imprecise and crude observations ranging from the scatter of dandelion seeds to the results of a competition with toy balloons, but little else had been done. Johnson made the first really accurate measurements of the diffusion of smoke clouds, showing great ingenuity and skill in so doing, and he established the basic empirical laws. Without this background it is doubtful if we would be now in the position of being able to calculate, with tolerable accuracy, the spread of a smoke cloud in " average " meteorological conditions.

Some of this work, in particular certain fundamental studies in meteorology, was published between 1921 and 1939, but the greater part remained as an " official secret " until after the end of the Second World War. Since 1945 there has been a great deal of work done on the properties of the lower atmosphere, and the subject has become more systematized.

What did we learn as the result of the pre-war studies?

Perhaps the first and most important fact was that the low atmosphere is far more complex in its structure than had been realized in the early years of this century. In fact, many fundamental problems still remain to be solved. On the credit side, however, there was much to show. First, we began to understand (and to a certain degree to explain qualitatively) the fundamental part played by the temperature structure of the atmosphere in controlling turbulence. This feature, which is almost impossible to reproduce on the laboratory scale, makes the task of the mathematical physicist extremely difficult when it comes to formulating a reliable mathematical theory of diffusion process in the atmosphere. In plain English, it became possible to predict with tolerable accuracy what happens to a smoke cloud emitted under an overcast sky with a moderate or high wind, that is, when the vertical gradient of temperature is small, but, even today, we have no completely reliable means of estimating the increase in concentration which results when the turbulence of the wind is checked by the formation of an inversion, for example, under clear night skies or with a winter anticyclone. Yet this is the condition of potentially greatest peril to those who live in polluted areas.

Heated Plumes

Some of the most interesting work that has been done in the post-war period relates to the dynamics of heated plumes. The first solution of the problem of the rise of hot air from a source of heat was given by Schmidt in 1941. I gave another solution, which is more amenable to computation than Schmidt's, and seemed to fit the laboratory experiments rather more closely, at the United States Conference on Air Pollution in Washington in 1950. These solutions referred to the rise of a plume of warm air in a calm, neutrally stable, atmosphere. In the same paper I gave a first approximation to the solution of a far more difficult and, for the purposes of pollution studies, a more important problem, namely, to calculate the path followed by a plume of hot gas which is not only rising under its own buoyancy but is also blown sideways by the wind.

The study of such problems not only provides the mathematician with some fascinating and formidable problems, but is essential for any quantitative solution of the problems which beset the designers of industrial plants. It is well known to all here that to avoid high concentrations of unpleasant or noxious gases in the vicinity of an industrial plant the golden rule is " Keep the stack orifice and the temperature of the effluent high." But how high, and how hot? We must be able to give reasonably accurate answers if we are to provide the engineer with something better than pious exhortations to do better than his predecessors.

Some interesting and important work has been done in Cambridge and in Australia on these problems. First, as regards the rise of smoke in a calm atmosphere in which temperature changes with height. This has been sturied by Morton, Taylor and Turner in Sir Geoffrey Taylor's laboratory and in Australia by Priestley and Ball working in the Division of Meterological Physics of the Commonwealth Scientific and Industrial Organization. Their results, which are in reasonable agreement, show that in a calm " average " atmosphere, the amount of heat generated at the source must be very greatly increased to change the height reached by the plume by a substantial amount. Thus, in such an atmosphere, smoke from a household chimney would reach about 200 ft, and the smoke from a large power-station chimney, about 3,000 ft. But the ratio of the heat sources is about 60,000!

The problem of the rise of a heated plume in a calm atmosphere is perhaps somewhat academic in relation to the real problems of atmospheric pollution. The case of greatest interest is that of the bent-over plume, when wind and buoyancy to some extent act against each other, although in the end each contributes to the desired dilution. This problem is much more difficult and a really satisfactory solution is yet to seek. The problem for the pollution engineer may be put thus. Because of its buoyancy the plume rises and ultimately it becomes nearly horizontal, travelling downwind at a height greater than that of the stack from which it came. The effect of the hot source is thus to give the stack a greater " effective height." Any increase in height has a considerable beneficial effect on concentrations of smoke at ground level downwind of the stack. It is a curious fact that although there are several different formulae expressing this effect, which look very dissimilar on paper, they give results which do not differ too widely when they are applied to the prediction of concentrations near the ground, which is what really matters to the engineer or architect.

In the Beaver Committee Report we adopted a simple empirical expression derived by the American meteorologist J. Z. Holland from observations on plumes at Oak Ridge, Tennessee. In the present state of the art this is probably as good as any, especially when it is realized that it is only occasionally that the relevant factors, heat output, wind speed and temperature gradient in the ambient atmosphere, will be known accurately.

Earlier I pointed out that the actual height reached by a plume in a calm atmosphere increases only slowly with an increase of heat at the source. This, however, should not be taken to imply that there is little point in conserving heat in a stack. Because of the marked effect of increase of stack height on ground concentrations—as the inverse square of the height—any lifting of the plume is desirable. The golden rule I stated earlier thus still holds, but now we can in many cases put figures into it.

Effect of Tall Buildings

The practical problem, however, does not end with the calculation of the effective height of the heated plume. Mathematicians can work only with " ideal " problems and in the examples quoted above it is assumed that the smoke gets away from the stack orifice without hindrance. In our cities the tendency today is to build tall buildings with cliff-like structure. (There is a good example of this type of building now going up near Waterloo station on the South Bank of the Thames.) With such buildings the natural wind is likely to form strong lee eddies near the roof, which cause a strong downwash from the flat roof. Any effluent emitted at roof level may be forced down the lee side of the building, thus producing high concentrations at ground level.

Problems such as these are not amenable to calculation and are best examined by tests with models in wind tunnels. The simplest solution would be to provide a tall " chimney pot " in the form of a stack mounted on the roof, so that the orifice is placed well above the region of disturbed flow, but usually this is unacceptable on architectural and aesthetic grounds. Fairing of the roof by the provision of sloping sides can also be of some assistance, but any pronounced departure from the flat roof is again unwelcome to most architects. Heating of the effluent alone is unlikely to provide a practical solution and the only way to overcome the difficulty appears to be to use a strong forced draught. In some tests recently carried out at the National Physical Laboratory for a building about 300 ft high it seems that the ratio

$$\frac{\text{exit speed}}{\text{wind speed}}$$

should lie between 2 and 3. For central London this indicates that the exit speed of the gases should not be less than 7 ft/sec (about 22 metres a second). This illustrates the kind of problem facing heating engineers who have to use oil- or coal-burning plant for a large building about 300 ft high.

The primary aim of this Conference is to discuss practical means of overcoming the evil of air pollution. I have dwelt at some length on the theoretical work which has gone on behind the scenes, as it were, because practical men can do little without figures, and it is the job of the scientist to supply the figures. As in all problems which bring in the atmosphere, it is vain to hope for great precision or accuracy. The number of variables is so great that any planning must be on a broad basis. What is essential is that the planning is reliable, and this brings us back once again to the scientists whose duty it is to establish a firm foundation.

Last year I attended an international conference on atmospheric diffusion at Oxford, and before that, in 1951, I had taken part in a similar conference at the Massachusetts Institute of Technology. It was interesting to compare the two. In 1951 most of the papers dealt with instruments and observations on atmospheric turbulence. In 1958 the mathematicians had got well on top and it looks as if they intend to stay there for a long time. In the early years of this century the subject looked very simple. Now it is so complicated that it needs a great deal of hard work and considerable technical skill to understand what the mathematicians are talking about, let alone consider practical applications. But that always happens when you let mathematicians in.

The Cure for Pollution

I make no apology for my fellow mathematicians in this matter because I know that their labours will not be wasted. The cure for pollution is simple—don't put nasty substances into the air. The studies which have been made on methods of eliminating, or greatly reducing, noxious products have, I believe, reached the stage at which we may say that the problem can be solved in most, if not all, cases. But this is a matter for the fuel engineers and I have no doubt that it will receive much consideration in your discussions.

It is heartening that at this stage in the history of the Society we can look on its labours with such satisfaction. The fact that you have gathered here, and in many instances travelled long distances, to discuss ways of overcoming one of the great evils of our age is also most heartening. It shows that we have a care for our neighbour. This great city was once notorious for the awesome character of its smoke-laden fogs and only seven years ago we had a painful reminder of the deadly nature of pollution. We still have our fogs and, as far as I can judge, they will be with us for ever. What we are justified in hoping is that never again will London suffer from the folly of man in poisoning his own air.

The programme in front of you is wide and interesting. " No man is an island," said Donne, and this might well be the keyword of this Conference. I wish you well in your deliberations.

II. 1

AIR POLLUTION LEGISLATION AND ADMINISTRATION IN GREAT BRITAIN

P. D. COATES, Ministry of Housing and Local Government, Great Britain

SUMMARY: The paper outlines the ways in which air pollution from industrial gases, industrial and domestic smoke, and grit and dust are dealt with. The requirements of the Alkali Act and the methods of the Alkali Inspectors, the Clean Air Act and the duties of the local authorities are also outlined. Research is being undertaken into aspects of air pollution which cannot be dealt with because of lack of technical knowledge.

Introduction

The space available permits only the briefest and most generalized conspectus of the British effort to control air pollution. The information is based on the law applicable in England and Wales, but there is no essential difference in Scotland.

Air pollution seems an inseparable concomitant of modern life but is one that can easily get out of hand unless controlled. The present British effort is concentrated on the control of certain major gaseous emissions from industry and of industrial and domestic smoke, grit and dust. The central Government through their Alkali Inspectors play a direct part in controlling the industrial emissions. Control of smoke, grit and dust rests largely with local authorities (the elected local councils).

The Alkali Act and the Alkali Inspectorate

The first Alkali Act was passed as long ago as 1863 to control works operating the Leblanc process for the manufacture of alkali (sodium carbonate). The first stage of this process involved the discharge to air of large volumes of hydrochloric acid gas. Following a public outcry a Royal Commission recommended that if 95 per cent of the hydrochloric acid gas could be trapped then the rest might, after adequate dilution, be discharged to air without serious risk. The adoption of the recommendation in the Act protected the public without stifling the industry, and although the Act has since been amended, extended and consolidated several times the dual objective of protecting the public and encouraging industrial growth has remained constant.

The essential requirements of the Alkali Act as it now stands are:

(a) No process controlled under the Alkali Act may be operated without a certificate of registration, renewable annually.

(b) A condition of registration is that the process must be fitted with the necessary equipment to enable it to be operated in conformity with the Act.

(c) The owner of any process must use " the best practicable means " for preventing the discharge of " noxious or offensive " gases to the atmosphere, and for rendering such gases where discharged harmless and inoffensive.

(d) There must be adequate maintenance of equipment for preventing the discharge of noxious or offensive gases and proper supervision of the process by the owner.

(e) There are certain statutory limits for the concentration of acids in waste gases, for example, for sulphuric acid concentration processes the limit is 1·5 grains (calculated as SO_3) per cubic ft.

The many industrial processes controlled under the Alkali Act now range from the original process to processes at oil refineries, iron and steel works and power stations (a complete list of controlled processes is annexed), and there is a procedure for bringing additional processes under control as necessary. Generally speaking processes have been brought under the Alkali Act either when the emission is particularly dangerous or offensive or when it is for technical reasons particularly difficult to prevent.

A small body of highly qualified Alkali Inspectors, appointed by and responsible to the Minister of Housing and Local Government, enforce the Alkali Act. In particular, they have the onerous responsibility of deciding what " the best practicable means " for preventing discharges may be at any given time and place. The Annual Reports of the Chief Alkali Inspectors are published each year and contain a wealth of valuable information. A copy of the 1958 Report is annexed for the information of overseas delegates.

Smoke

Much the most obvious form of air pollution in Great Britain is smoke, about half of which comes from the traditional British open coal fire. In spite of sporadic legislation over the centuries, the earliest known example dating from 1273, some British centres of population and industry must be among the most heavily smoke-polluted areas in the world.

The disastrous London smog of December 1952, when several thousand people died, did at least make it clear that the existing level of pollution over the big cities could no longer be tolerated. The Government set up a Committee under the chairmanship of Sir Hugh Beaver to study the problems of air pollution and to make recommendations for action. The Clean Air Act of 1956, which opened an entirely new chapter in the story of British control of air pollution, was largely based on the Committee's findings.

The Act greatly strengthened previous control over smoke emitted by non-domestic sources. The discharge from chimneys of dark smoke, defined as Ringelmann shade No. 2, is prohibited, with small exceptions to permit operations such as periodic cleaning and raking of furnace fires and subject to a period of grace, ending in 1963, where it is not practicable to alter existing plant at once. Further, all new furnaces installed in future must be capable of operating smokelessly when burning suitable fuel. The local authorities are responsible for enforcing these provisions.

The entirely new feature of the Act is, however, that for the first time local authorities are given wide powers to deal with domestic smoke. Subject to confirmation by the Minister of Housing and Local Government, the Minister responsible for the administration of the Clean Air Act, local authorities can make orders prohibiting domestic and other smoke in any part of their districts.

No means have yet been found of burning coal smokelessly in an open domestic grate. This means that householders in a smoke control area must change over from coal to a smokeless solid fuel, normally coke, unless they use electricity, gas or oil. Some smokeless solid fuels will not burn in the usual existing coal grates, and householders are therefore given a grant of 70 per cent of the cost of their conversion or replacement, 30 per cent being met by the local authority and 40 per cent by the central Government.

The object of the Act is to ensure that fuels are burnt as efficiently and smokelessly as possible. It is not its intention to discourage the burning of solid fuel, since coal and solid fuels derived from coal remain fundamental to the British economy.

The response of local authorities to the Act has been encouraging. At the end of the first two years after its enactment smoke control orders covering some 243,000 premises and 41,000 acres of land had been made or were in active preparation. There is, however, still a very long way to go, and faster progress is now needed if the big cities are to be freed of the present incubus of smoke in a reasonable time. At the end of the two-year period the Minister therefore asked all local authorities in badly affected areas to prepare individual programmes for establishing smoke control areas over the next five years.

Grit and Dust

Control of grit and dust (and smoke) from processes registered under the Alkali Act is the responsibility of the Alkali Inspectorate. In all other cases the Clean Air Act requires the use of all practicable means to minimize grit and dust from furnaces and every new furnace over a certain size has to be equipped with arrestment plant, the local authorities being responsible for enforcing these provisions.

Public Health Acts

Where an emission to air not otherwise covered constitutes a legal " nuisance ", action can be instituted against it under the Public Health Acts.

Future Progress

Control under the Alkali Act will as before be directed towards reconciling the need for clean air with the requirements of a thriving and progressive industry. New technical developments in industry constantly bring new problems, but there is no reason to fear that the administrative and legal framework will fail to meet these constantly recurring challenges. As one example of what has been achieved by co-operation and goodwill and the application of new techniques to new situations, the throughput of the British heavy chemical and allied industry has been trebled since 1938 but tests show that the ground level concentration of chemical contaminants is no higher than it was before the war.

A satisfactory legislative framework has been provided for the major national campaign against smoke, grit and dust which is now under way.

There are however, other aspects of air pollution on which little or no progress can be made in the present state of scientific knowledge. Accordingly the central Government have formulated and co-ordinated an extensive programme of research into the nature, distribution, causes, effects and prevention of various forms of air pollution. The research is being carried out partly by the central Government and partly by independent bodies, including industrial research associations.

II. 2

A PLANNED INVESTIGATION OF AIR POLLUTION IN GOTHENBURG, SWEDEN

CYRILL BROSSET, Professor of Inorganic Chemistry, Gothenburg.
HANS RONGE, Professor Public Health, Lund.
RAGNAR SPAAK, Principal Medical Officer of Health, Gothenburg, Sweden.

SUMMARY: An increased amount of air pollution has been noticed in Gothenburg as the result of the establishment of an oil refinery and a number of district heating plants. Gothenburg is also the biggest port in Scandinavia, and has a number of large industrial plants. Since 1945 measurements have been taken using English instruments situated at one central point in the town and it has been decided that these observations should be extended by placing several batteries of instruments over a wider area. A team of scientists and medical experts has been formed and it is proposed to take measurements of solid pollutants, 30 standard deposit gauges, five lead peroxide instruments and five daily smoke filters distributed throughout the town. A pilot survey is also to be made on the effects of varying atmospheric pollution on the state of health of a small group of chronic bronchitics. This investigation is the first of its kind in Sweden and is planned to start in October 1959.

During the last decade the Public Health Department of Gothenburg has followed with special interest the question of air pollution in the city. The stimulus was the starting of an oil refinery in the northwestern part of the town. From people living within a distance of one to three kilometres there was a shower of complaints of bad smell. This odour problem has been tackled by the oil company in co-operation with the Public Health Department with a certain degree of success. Other sources of air pollution are the central heating plants, which successively since 1945 have been established in different quarters within the town. Each of them serves from 1,000 to 5,000 families. There are now some 25 of these central heating plants. They are usually heated with fuel oil but often used to burn refuse from the houses too. This is done in ordinary hot water furnaces. There have been many complaints of sootfall, bad odour and so on from people living in the vicinity. From the viewpoint in question it is also worth mentioning that Gothenburg has the biggest port in Scandinavia and many large industrial plants, such as three shipyards, a motor-car factory and so on.

The climate of Gothenburg may be characterized as rather mild but variable and with a high yearly rainfall. During the winter-season mist and haze appear now and then.

In 1955 the Public Health Department acquired one Standard Deposit Gauge, two Lead Peroxide Instruments and one Daily Smoke Filter and Volumetric Sulphur Dioxide Apparatus from England. These instruments were placed at a central point in the town. The results obtained showed that smoke pollution fluctuated very much from day to day. This fluctuation seemed to be correlated to the varying weather conditions. Also a marked difference between the seasons was noted. Several times during the winter months periods of temperature inversions were noticed and these observations were confirmed by the meteorological station of the airport just outside Gothenburg.

Isolated observations like these have stimulated the interest in a more comprehensive study of the present state of air pollution in our city. It is obvious that in order to get reliable data several batteries of instruments must be placed at different points in the town. Such an investigation ought to be carried out as a team work between medical officers, technical and meteorological specialists.

A team has now been formed consisting of two Medical Officers of Health, one Professor of Public Health, two Professors of Technology of the Chalmer's College of Technology, one of whom is a Professor of Chemistry and the other a Professor of Ventilation and Air Conditioning Technique and, finally, one Meteorologist. A plan has been outlined including air pollution sampling, meteorological observations, dust analyses and a medical pilot survey. Financial contributions to the investigation have recently been made by the City Council of Gothenburg and further by three of the Government Research Councils and one private Scientific Fund.

The sampling of precipitating solid pollutants and rainwater will be done in 30 Standard Deposit Gauges, placed in dwelling areas, in industrial areas, in " mixed " areas and in unoccupied areas. Lead Peroxide Instruments will be placed together with the Deposit Gauges. Five Daily Smoke Filters and Volumetric Sulphur Dioxide Apparatuses will be set out in the central parts of the town. In order to measure the size of the particles and size distribution, solid pollutants will be collected by an electrostatic precipitator out-of-doors. Recording of temperature and humidity will also be made at ground level and every 20 metres up to 80 metres above ground level. The meteorological instruments will be fastened along a big gas tank situated in the centre of the town.

In connection with these observations we also intend to make a pilot survey regarding the possibilities of following the effects of varying atmospheric pollution on the state of health of a small group of patients suffering from chronic bronchitis. This group will consist of 20 persons, living in the centre of the town where the pollution is measured daily. When performing this survey we will rely upon the experience that has been gained in England.

This investigation, the first of its kind in Sweden, is planned to start in October 1959. The reason why we mention it before this assembly of air pollution specialists is that we hope to get valuable hints as to the realization of the programme, and to initiate a close contact with other scientists working with similar studies in other towns.

II. 3

THE SUCCESSFUL ANTI-SMOKE PROGRAMME OF ST. LOUIS, MISSOURI, U.S.A.

JAMES H. CARTER, Commissioner of Smoke Regulation, City of St. Louis, Mo., U.S.A.

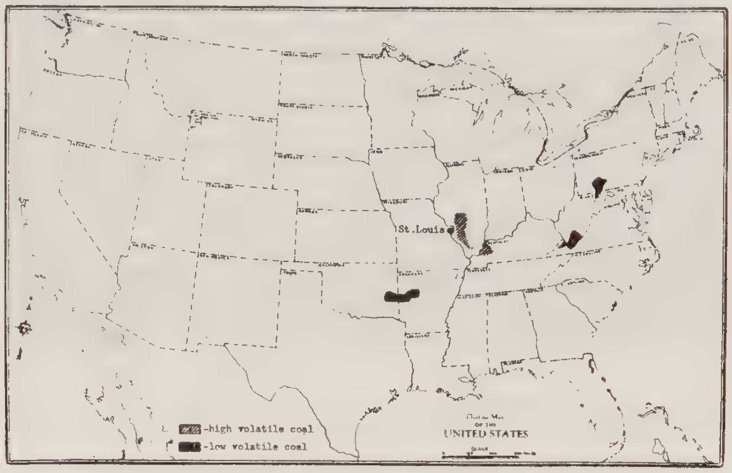
SUMMARY: The amount of air pollution in St. Louis has been reduced enormously in the last 20 years and this paper sets out the provisions of the legislation by which this was accomplished, the principles upon which these provisions were based and the means employed by the control office in their enforcement. The amount of pollution in St. Louis was caused largely by the availability of a large coalfield, the coals of which are of a volatile character. The attack on air pollution was based on the principle that all those who desired to fire by hand must use a smokeless fuel while others must use mechanical fuel burning equipment. The provisions of the ordinance or bye-law by which this principle was put into effect are listed. The city is divided into nine districts each with an inspector who has the duty of enforcing the legislation. There are provisions for chimney dust loading tests. All new plant has to be approved by the enforcement authority and all coal dealers in the city require a permit to operate. The division publishes its regulations in booklet form for the design of fuel plant and also a booklet on "Sources of Solid Fuels," which gives analyses of coal from several hundred mines in various parts of the United States. There is a staff of 20 engineers, inspectors and office workers.

A visitor returning to St. Louis today after an absence of 20 years would hardly recognize it as the city he left in 1939. Gone are the smoky palls which obscured the sun, the clouds of soot which settled on every unprotected surface, the smell and taste of sulphur which persisted all winter. In their places are clear and sunny skies, newly cleaned buildings and clean, fresh air to breathe.

The story of this accomplishment is an interesting one. It has been told many times and will not be repeated here. Here we shall state, briefly, the provisions of the legislation by which this was accomplished, the principles upon which these provisions were based, and the means employed by the control office in their enforcement.

Let us first examine the circumstances which made the legislation necessary. Immediately across the Mississippi River from St. Louis lies one of the large coal fields of the North American continent (see map). Much of it an easy haul by highway, and all only a short freight haul away, this plentiful supply of excellent fuel contributed greatly to the city's growth as an industrial metropolis. But the Illinois coals are of high-volatile rank, many of them (particularly those nearest St. Louis) also high in ash and sulphur. Proximate analysis ranges for those readily available to St. Louis are about as follows, in percentages:

Volatile	32–41
Ash	8·5–16
Sulphur	2·5–5.5



SOURCES OF BITUMINOUS COAL FOR ST.LOUIS, MO

Not only was this fuel burned under industry's furnaces and boilers, it powered the locomotives of the area's many busy railroads and it supplied heat to the city's thousands of homes and commercial buildings.

Coal of this type is not easily fired smokelessly by hand. In industrial furnaces, where temperatures can be kept high and provisions made for the rapid and intimate mixture of air with the volatiles, this is possible. But these conditions are not present in the stoves and furnaces used for winter heating. By the early 1930's many futile attempts had been made to teach the people of St. Louis to fire their smoky coal smokelessly. A different approach was obviously necessary.

The new approach can be summed up in these words: that all those who desire to fire by hand must use a smokeless fuel, others must use mechanical fuel burning equipment. The ordinance—or by-law—by which this was put into effect is the summation of legislation enacted in 1937 and 1940. After establishing the Division of Smoke Regulation and providing for its staff, this ordinance:

(1) defines dense smoke as equal to or denser than number two on the Ringelmann chart and prohibits its emission except for short, specified periods.

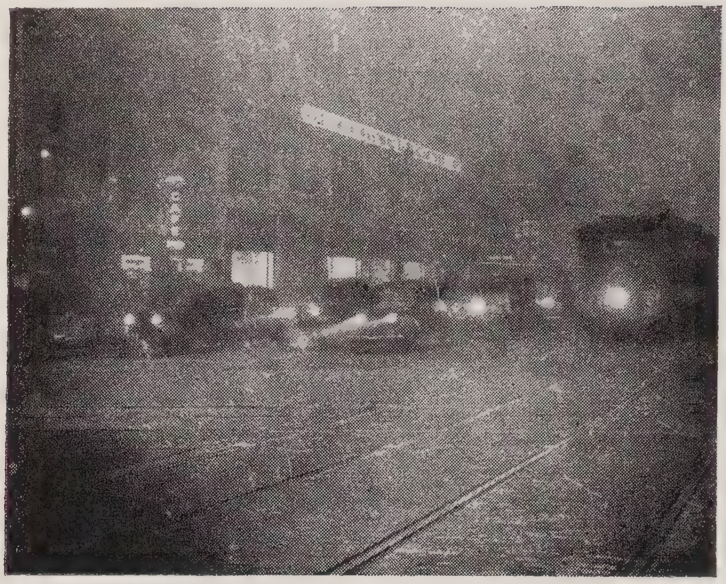
(2) specifies a maximum chimney dust loading of 0·85 lb per 1,000 lb of flue gas and provides for the testing of chimneys to check for compliance;

(3) requires that solid fuel for mechanical firing, under 2 in. in top size, which contains over 12 per cent ash or 2 per cent sulphur, must be washed until its ash content does not exceed 12 per cent;

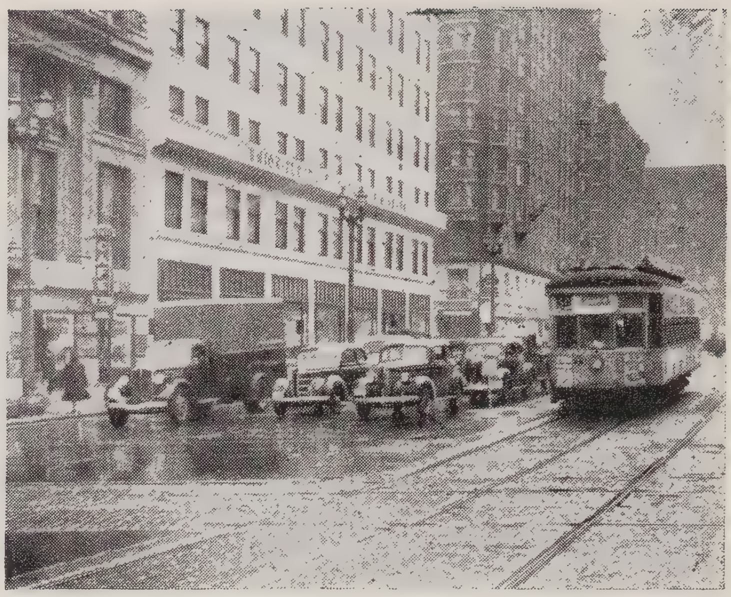
(4) prohibits the sale or use of any solid fuel for hand-firing containing over 23 per cent volatile matter on a dry basis;

(5) provides that no fuel-burning or refuse-burning device shall be installed or erected until a permit has been obtained from the division office;

(6) requires dealers in fuel or refuse-burning devices to make periodic reports of their sales;



Twelfth and Olive Streets, St. Louis, Mo., U.S.A., at 10.00 a.m. on 28th November 1939.



The same spot, 52 weeks later, with the low-volatile provisions of the anti-smog ordinance in effect.

(*Both photos by St. Louis Post-Dispatch*)

(7) permits employees of the division to enter any suspect building at any reasonable hour;

(8) gives the commissioner authority to seal offending equipment;

(9) establishes an appeal board and sets forth a procedure whereby appeals from the commissioner's rulings can be taken;

(10) provides for fines upon conviction in court for violations of any of the ordinance provisions.

For enforcement purposes, the city is divided into nine districts with an inspector assigned to each. While daily patrolling his district, the inspector observes the many chimneys and reports to the office all those seen smoking in excess of ordinance limitations. The office, in turn, sends by mail a notice of the violation to the responsible party. When violations continue, conferences are arranged and every effort made to find the cause of the smoking and have it corrected. In cases where owners are not co-operative, action is instigated in the city courts or a hearing is held and the offending equipment sealed. Either of these punitive actions forces remedial measures by the operator.

The division has apparatus and trained personnel for the conduct of chimney dust loading tests. However, the ordinance provides that these tests be made at owner's expense and it is preferred that they be run by impartial agencies with the approval of, and under the observation of, the division's personnel. A hundred or more such tests have been conducted here in St. Louis.

While reducing pollution from the equipment already in use, it is important that the situation is not continually made worse as new devices are installed. The division has published, in booklet form, its own regulations for the design and setting of burners for oil, gas and solid fuels as well as incinerators for various types of refuse. Plans for the installation or erection of all such devices are filed with the division where each is examined and, if approved, a permit issued. When work is completed, each installation is inspected to assure that it meets all requirements, and, when accepted, is so labelled by the district inspector. The ordinance provision that dealers in this type of equipment must report their sales is an aid in the enforcement by helping to prevent " sneak " installations which might otherwise be made without permits.

Enforcement of the solid fuel provisions is abetted by a concurrent ordinance which requires that all coal dealers doing business in the city have a permit issued by the division so to do. The permit is renewed annually, and provisions are made for its revocation upon cause. Issuance of the permit is dependent upon the filing of a thousand-dollar performance bond by the applicant. Every vehicle used by a permittee in solid-fuel transport is registered and is identified by a decalcomania on the vehicle's windshield.

The division has in its files analyses of coals from several hundred mines located in various parts of the United States (see map). These include not only the Illinois mines from which St. Louis receives the bulk of its stoker-fired coal, but also a few mines in Kentucky, which compete for a share of this market. Most of the city's low-volatile coal comes from the states of Virginia and West Virginia with occasional shipments from Pennsylvania and Maryland. The city's second source of low-volatile coal is the Arkansas-Oklahoma field. From time to time a compilation of these mines and their products is published in a " Sources of Solid Fuels " booklet which is made available, *gratis*, to the trade.

Enforcement of the many ordinance provisions requires the full-time efforts of a staff of 20 engineers, inspectors and office workers. It pays off in a cleaner and brighter city.

II. 4

LEGISLATION AND ADMINISTRATION IN SMALL STATES

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SUMMARY: The author discusses legislation and administrative requirements for clean air in small or less industrialized nations, stemming from personal consideration of the question in the Republic of Ireland. An outline is given of an appropriate form of Act, which it is suggested should give flexibility and ability to meet changing conditions by means of Regulations. The form and functions of an administrative Steering Committee are described.

Air pollution in some small and as yet industrially under-developed states can present legislative and administrative problems more difficult of solution than those of highly industrialized nations.

The main reasons for this are:

The Fluidity of the Industrial Position

National industry not largely founded upon home produced raw materials is apt to progress sporadically and be diffuse in character. A clear pattern is not easily discernable. Consequently, it is almost impossible at any period to draft a statute on air pollution which, satisfactory for conditions at that time, can be guaranteed to remain satisfactory for a period of years. Statute law fructifies slowly and in a modern democracy there is a reluctance towards early modification or frequent amendment.

The generally limited number of pollution foci

The presence of pollution may not only be restricted to a small number of centres but may also be difficult to demonstrate. Influencing public opinion, therefore calls for an educational effort of greater relative proportions than is necessary in fully industrialized states.

Finance

This requires no labouring.

Staff

This problem is partly coupled with Finance above. A corps of specialists is neither feasible nor, in the conditions postulated, justifiable. Specialist assistance will be required from time to time but, at field level, there is a need for some type of existing official who can absorb the duties so as to give a complete and continual coverage of the areas affected, or likely to be affected.

In those circumstances suitable legislation needs to be flexible both in application and in content. Again, in the postulated circumstances, permissive rather than prohibitive legislation is to be preferred, although the present position regarding maximum allowable concentrations militates against a wide application of the permissive form. The pattern of legislation suggested is a simple enabling Act containing power to make regulations for promoting the cleanliness of the atmosphere.

The Act could give power to make regulations for:

(a) Setting up a small Steering Committee at Government level to advise, co-ordinate and integrate the operations of all agencies concerned in the problem.

(b) Controlling specific potential sources of air pollution, e.g. chemical factories.

(c) Controlling sources of pollution from smoke, dust, grit and gases.

(d) Dealing with potential sources of air pollution from radio-active material.

(e) Promulgating maximum allowable concentractions of pollutants in the *atmosphere.*

(f) Covering the recruitment and training of staff and payment of fees.

(g) Allowing grant-aid for schemes of measurement, special investigations and plant or fittings conversion.

(h) Prescribing penalties for contraventions.

(i) Zoning controls.

Future developments of potential sources of air pollution not contemplated or foreseen at the time of its passage could be covered by such an Act. Also regulations need only be made as required (confer (d) above) and could be revoked, revised or amended when necessary without incursion upon parliamentary time.

It is considered that the advantages occuring in the given circumstances from such a form of legislation outweigh the well-known arguments against Government by regulation.

The constitution of the Steering Committee would be most important. The control of air pollution requires the skill of a large number of professions. Nevertheless, for financial and other reasons it would be unsuitable for a small nation to constitute a large and unwieldy committee. Its detailed constitution will, to some extent, be governed by local usage and wide variations are possible. Basically, it is suggested that it should consist of an independent chairman, a senior administrative officer from the Government Ministry concerned; a medical member of the local authority preventive medical service where such exists; a " research " representative, e.g. from University staff; and a technical officer versed in environmental hygiene. A small unit of this description, backed by power to obtain advice from specialist sources and charged not only with the task of advising the administration but also of promoting national and international liaison, is more likely to be effective than a large body with simple advisory functions.

Another essential is the availability and proper use of staff. It is convenient to divide staff into those required for field duties, i.e. enforcing regulations, carrying out inspections, and simple measurements and, on the other hand, staff engaged on research or special forms of investigation. These latter will be University and medical school staff, public Analysts and perhaps private firms. Occasions will arise where integration and co-operation between research staff and field staff will be needed and this would represent another function of the Steering Committee.

For field duties the small State is unable to support an elaborate organization, e.g. three separate officers for, respectively, observation, investigation and remedy. Neither may it be feasible to recruit even a limited number of specialist field officers capable in all circumstances of combining the three functions mentioned above. Another important factor is that field staff are in the best possible position to act as educators, and for this, frequent contact must be made with both offenders and possible offenders. A fairly large number of personnel will be required for coverage even though their active operations may not always be whole-time. One must seek therefore personnel who might by reason of analogous duties prove suitable.

States operating a Health Inspector or Sanitarian Service as part of their local authority organization, are in a more favourable position than those who do not. These officers are already engaged closely with the public in the execution of other vital environmental health duties. It may, of course, be necessary to give them additional training to cover the problems they will meet and to use their unique opportunities of educating both operating personnel and the general public.

Their chief use will be in dealing with pollution from smoke, dust, grit and odours. They might at a later date be employed in certain phases of the control of pollution from radioactive airborne material.

Where Health Inspectors are not employed it is likely that there will be considerable difficulty in providing the necessary coverage. The Health Inspector is nowadays widely recognized as an essential part of local environmental hygiene services and it might well be that States not already possessing them would decide to recruit them not solely for air pollution duties. If not, it is suggested that the local enforcement of legislation on air pollution should be vested in whatever officers now operate the local sanitary services such as water supply, drainage and so on.

In the postulated circumstances the more involved industrial processes such as chemical works, oil refining and power generation are likely to be small in number though individual units may be large. It would therefore be better that supervision of such processes should be by the central authority, whence specialized knowledge is usually available and in any event uniformity of treatment is easier to maintain. The same case cannot always be justified where the numbers of these installations allows the accumulation locally of a reservoir of experience and knowledge of topographical and local meteorological peculiarities. For special advice to local staffs it is suggested that a panel be drawn up by the Steering Committee of experts whose services would be available on a fee basis.

Finally there will be required, directed by the Steering Committee a continual emphasis on the " team " attitude with, as a corollary a good system of both vertical and horizontal liaison.

The foregoing personal ideas and suggestions stem from practical consideration of air pollution in the Republic of Ireland. Existing legislation is antiquated and was never likely to be satisfactory. This was not so important when industry was very small. In present conditions of increasing industrialization and growing centres of population, the law is completely unsuitable.

In this situation new and comprehensive air pollution legislation is necessary and the suggestions made are intended to utilize as far as possible the existing Environmental Health Services organization.

II. 5

THE PRESENT DEGREE OF AIR POLLUTION AND THE RELEVANT LAWS AND REGULATIONS IN FORCE IN THE FEDERAL REPUBLIC OF GERMANY

(Contribution by the Federal Ministry of Labour and Social Affairs, Bonn)

SUMMARY: The problem of air pollution in the Federal Republic has increased with the growth of industry since the last war. The Industrial Code provides for prior approval of industrial plants. Police regulations control some forms of pollution as a measure of public safety. Motor vehicles are controlled under the provisions of a separate ordinance. Adjustments of the laws and regulations are under active consideration to meet changing conditions.

For about a hundred years scientists in Germany have studied the damage caused by smoke. Renowned German scientists have elaborated test procedures and developed instruments and methods with a view to measuring emissions from industrial establishments and to keeping them within tolerable limits. Before World War II immissions in general did not exceed tolerance thresholds. The situation changed after the end of the war. After the complete break-down it was important, first of all, to rebuild the establishments destroyed in order to be able to start operation as soon as possible. Naturally many measures were neglected at that time because they could not be carried out for technical or for economic reasons. While the Federal Republic was spared any smog catastrophies, as in German private homes coal is usually burnt without smoke, it could not be helped that today the contamination of the atmosphere over large areas is such that it becomes a problem of national, and partly even of international, importance. This aggravation of the situation must be attributed to the creation of new industrial plants, to the neglect of existing plants, the considerable increase in the density of the population, the processing of raw materials rich in ballast, etc. Measurements of present air pollution over industrial areas showed that in some areas of the Federal Republic of a size of about 20 to 30 sq km precipitations of dust have reached an amount exceeding the tolerance threshold. It is considered that the permissible limit is exceeded where the precipitation of inert dust amounts to 3 kg per 100 sq m a month. It has been ascertained that air pollution has caused damage to vegetation, in particular to pine woods, though such damage must primarily be ascribed to dust and not to sulphur dioxide originating from the combustion of fuel. It was found that under unfavourable atmospheric conditions the critical value of 0·5 mg sulphur dioxide per cu m of air was exceeded in some areas.

The legal provisions in force in the Federal Republic of Germany concerning air pollution control are laid down both in public and in civil law.

The provisions contained in Secs. 16, 24, and 25 of the Industrial Code ensure protection against air pollution under public law with regard to immissions from industrial undertakings. These provisions prescribe that approbation from the appropriate authority must be obtained prior to the establishment of certain plants susceptible of entailing considerable disadvantages, dangers or annoyance for the owners and inhabitants of the neighbouring premises or for the community at large. The law contains a comprehensive enumeration of the plants in question.

A considerable number of plants contributing to atmospheric pollution, such as chemical factories, metallurgical plants, cokeries, cement mills, foundries, etc., come within the scope of these provisions. In the course of the procedure of approbation it is examined whether the plant is susceptible of causing considerable danger, disadvantage or annoyance to others. The approbation is subject to the fulfilment of certain conditions and obligations. The law does not prescribe any maximum limits for emissions. Thus the competent authorities are in a position to adjust the conditions to the latest technical development. There are no provisions, however, allowing the imposition of any additional conditions, once the approbation has been given. There are similar provisions concerning mining undertakings. With regard to emissions from motor vehicles there are special prescriptions contained in the Ordinance concerning the admission of motor vehicles (Straken-Verkehrs-Zulassungs-Ordnung), promulgated in 1953.

In addition to these statutory provisions there are police regulations and regulations concerning the maintenance of public order which provide for an intervention in case of air pollution where it becomes necessary to avert dangers menacing public safety or public order. According to the consistent practice of the Supreme Court of Administration public safety is primarily to be understood as the protection of the public and of the individual citizen against any damage to his life, health or property.

As far as civil law is concerned, the relevant provisions are contained in Sec. 903 and Sec. 906 of the Civil Code. Sec. 903 enunciates the principle that the owner of property may dispose of it at his discretion and may in particular exclude anybody else from interfering with his rights, unless there are any laws or titles of third persons restricting such power of disposition. Sec. 906 limits the right laid down in Sec. 903. This section provides that, under certain circumstances, the owner of real property must tolerate a number of immissions specified in this section (obligation of tolerance).

So for instance the owner of real property must suffer immissions from another real estate if such immissions are of no substantial consequence. A third person must also tolerate substantial immissions, if the person prejudicing the enjoyment of his rights, uses his tenement in conformity with its location and with local customs.

In general it can be said that the fundamental principles at the basis of the relevant provisions of the public law have held true. It becomes, however, necessary to adjust them to the new technical, economic, and social development. New types of establishments have been set up which are not yet listed among the establishments requiring approbation by the authorities. It has also proved a disadvantage that, once an entrepreneur has been authorized to operate an establishment, it is not possible subsequently to impose any further obligations on him; furthermore measurements to control compliance with the conditions imposed upon the entrepreneur at the time the approbation was given must be carried out at the expense of the authorities.

With regard to civil law it should be stated that the obligation to tolerate immissions is considered too far-reaching under present circumstances. The German Parliament is at present, on their own motion, preparing a bill which is intended to adjust existing regulations to the new technical, economic, and social development. When this bill has been passed, Government will have to elaborate a new ordinance setting forth all technical installations which require official approbation. In overall administrative regulations, up-to-date techincal rules will be laid down designed to serve for the guidance of the authorities in charge of the official procedure of approbation. In this task the Federal Government has the advice of a Commission for the " Control of Air Pollution " set up at the " German Engineers Association ". This commission has more than a hundred expert members and is subsidized by Federal Government. The Federation, the " Lander ", the communities, and industry promote all research activities which may benefit air pollution control In order to encourage and accelerate the installation of devices for the reduction of air pollutants in immissions from industrial establishments entrepreneurs, under certain circumstances, are granted tax relief.

Federal Government takes the view that the problem of air pollution control cannot be solved by legal measures alone. A solution of the problem is a task incumbent on the entire community, and all parties concerned must realize their responsibility in this field. Industrialists, in principle, are ready to make use of the new technical possibilities for the control of dust and exhaust gas. In some branches of industry a noticeable reduction of immissions was registered in recent years.

II. 6

AIR POLLUTION PROBLEMS IN THE FEDERAL REPUBLIC OF WEST GERMANY

Dr.-Ing. KURT GUTHMANN, Verein Deutscher Eisenhüttenleute, Düsseldorf

SUMMARY: Germany has recognized that legal regulation of Air Pollution would be inadequate and impossible unless based on proper scientific and technological data. In 1955 a Verein Deutscher Ingenieure committee for the prevention of Air Pollution was established. The committee is made up of experts from many German industrial associations and of scientists of many different disciplines. This committee supplies the legislators with technical data. Investigations are carried out by private and university research institutes, and so far 1·3 million DM have been made available out of public funds. It is not possible to introduce a comprehensive special law at present, but the draft proposal for amendment of trade regulations and the supplement of the German Civil code has been placed before the Bundestag. The committee for the prevention of Air Pollution has established directives, applicable to new plants, which limit the permissible dust loading of the outside atmosphere, deal with the reduction of dust emissions and contain directives and explanatory notes regarding the reduction of dust-like emissions.

The West German industry is highly conscious of its air pollution and air hygiene problems. When, in 1954, parliamentary circles considered a legal regulation of air pollution and the problem was put before the Bundestag and the Federal Government, it was recognized that such regulation alone would be inadequate and impossible to implement unless it was based on a sufficient mass of proper scientific and technological data.

The proposals made by the Verein Deutscher Ingenieure were backed by the Federal Government, and in 1955 the VDI committee for the prevention of air pollution was established. From the outset, the natural sciences involved were to co-operate and so were the offenders and victims of air pollution. Experts of the following associations constitute the committee personnel:

Deutsche Gesellschaft fur Hygiene und Mikrobiologie (German Society for Hygiene and Microbiology); Gesellschaft Deutscher Chemiker (Society of German Chemists); Deutscher Wetterdienst (German Meteorological Services); Gesellschaft Deutscher Metallhutten-und Bergleute (Society of German Metalworkers and Miners); Steinkohlenbergbauverein (Association of Collieries); Technische Uberwachungsvereine (Associations for Technical Control); Verein Deutscher Eisenhuttlenleute — VDI — Fachgruppe Staubtechnik (VDI Technical Group for Dust Problems); Vereinigung der Grosskesselbesitzer (Association of Owners of Large Boilers).

Scientists of universities and institutes for biology, chemistry, forestry and agriculture, medicine, meteorology, physics, technology, the federal Association of the German Industry (various industrial groups), the German railways and road traffic authorities, the German farmers' association, top municipal corporations, the development board of the Ruhr mining area, responsible government departments, control authorities.

The scientists and experts of the Federal Republic serving on an honorary basis on this committee to help solve these problems come from the following vocations:

Physicians	12
Veterinarians	3
Botanists	8
Agriculturists	7
Foresters	7
Chemists	10
Physicists	9
Meteorologists	7
Miners	4
Metallurgists	11
Representatives of authorities ...	8
Engineers of various vocational and industrial groups	50
Others	7
	143

This committee supplies the legislator with technical data such as the maximum allowable pollution loads. Investigations into measuring methods and into emission, distribution and effects of dust and gases are carried out by private and university research institutes for which considerable sums are required. So far some 1·3 million DM have been made available for these purposes out of public funds; about the same sum will be needed for research projects on which work has not yet been started.

Accurate objective *measurement of dust and gas emission* is a pre-requisite for ascertaining the extent of air pollution caused by an emission source. The distribution of material discharged to the atmosphere depends on meteorological conditions also. These conditions and the relation between emission and rainfall, in other words the natural causes of dust and gas distribution, should be known if the minimum clean air standards are to be satisfied. Also it should be possible to measure the dust and gas levels, or concentrations and precipitations of air admixtures, in a zone affected by air pollution. For this purpose improved measuring methods are being worked out.

Finally, the biological effect of air pollutants on human, animal and vegetable life should be examined. Based on this knowledge it will be possible to define the minimum standards of acceptable concentrations and precipitations of dust and gases in the neighbourhood of air pollution sources, and to estimate the reduction of dust loading and the remedial measures that are required.

In 1957, a report was submitted to the Federal Government giving a survey of the:

present state of air pollution in German and abroad;
legal measures abroad;
establishment of a comprehensive research program;

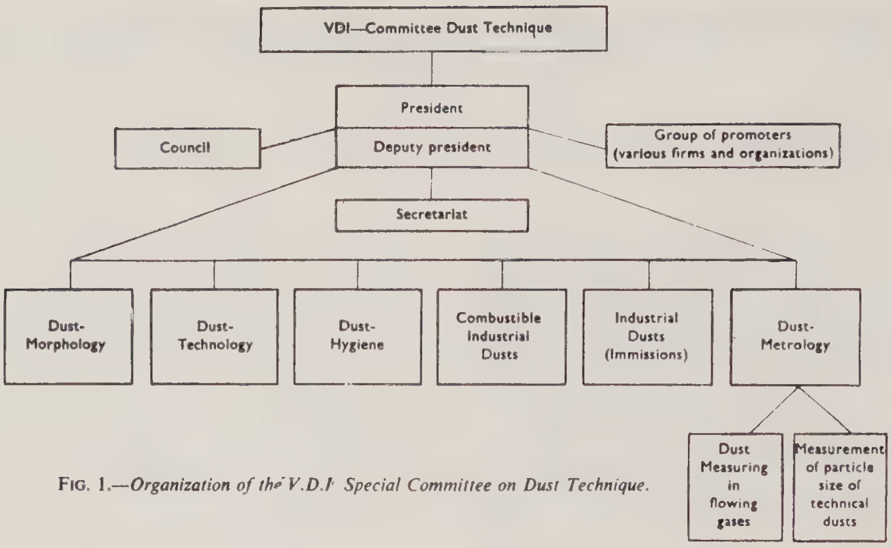
VDI—Committee Dust Technique
President
Deputy president
Council
Group of promoters (various firms and organizations)
Secretariat
Dust-Morphology
Dust-Technology
Dust-Hygiene
Combustible Industrial Dusts
Industrial Dusts (Immissions)
Dust-Metrology
Dust Measuring in flowing gases
Measurement of particle size of technical dusts

FIG. 1.—*Organization of the V.D.I. Special Committee on Dust Technique.*

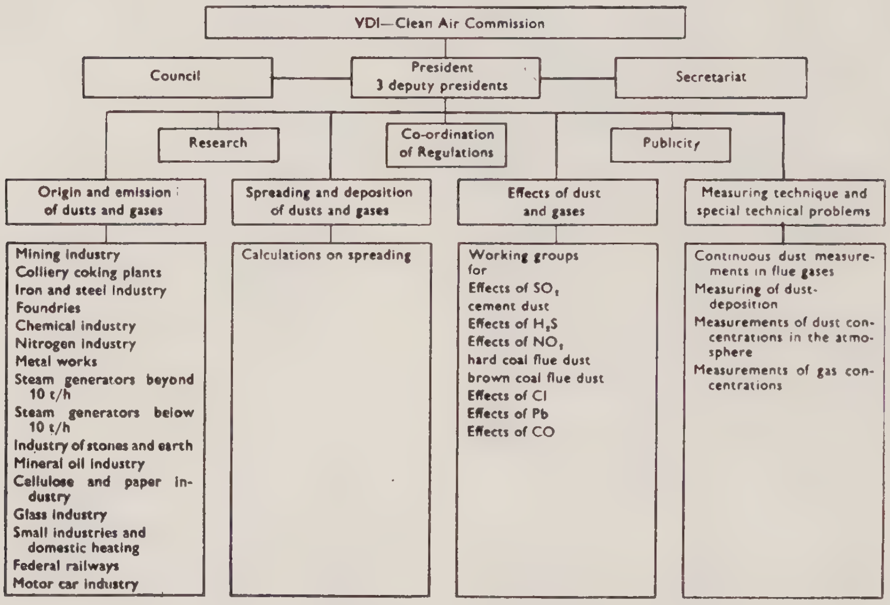
VDI—Clean Air Commission
Council
President
3 deputy presidents
Secretariat
Research
Co-ordination of Regulations
Publicity
Origin and emission of dusts and gases
Spreading and deposition of dusts and gases
Effects of dust and gases
Measuring technique and special technical problems
Mining industry
Colliery coking plants
Iron and steel industry
Foundries
Chemical industry
Nitrogen industry
Metal works
Steam generators beyond 10 t/h
Steam generators below 10 t/h
Industry of stones and earth
Mineral oil industry
Cellulose and paper industry
Glass industry
Small industries and domestic heating
Federal railways
Motor car industry
Calculations on spreading
Working groups for
Effects of SO_2
cement dust
Effects of H_2S
Effects of NO_2
hard coal flue dust
brown coal flue dust
Effects of Cl
Effects of Pb
Effects of CO
Continuous dust measurements in flue gases
Measuring of dust-deposition
Measurements of dust concentrations in the atmosphere
Measurements of gas concentrations

FIG. 2.—*Organization of the V.D.I. Clean Air Commission.*

proposals and means for reducing air pollution, and recommendations for legal regulations.

In Germany it will not be possible, for the timebeing, to introduce a comprehensive special law; however, a " draft proposal for the amendment of trade regulations and the supplement of the German Civil Code," which will meet the wishes of the public, was put before the German Bundestag and may become law in the course of this year. The amendments will affect Section 16 and 25 of the trade regulations and Section 906 of the Civil Code; for instance, the acceptance of emission controls and the possibility of subsequent enforcement of emission limits on plants which have already been licensed are laid down. These plants will be exempted from the law; regulation will be by ordinances. The liability of the neighbourhood to accept emissions whose suppression would be technically and economically feasible will be made less stringent.

The committee for the prevention of air pollution establishes directives limiting the permissible dust loading of the outside atmosphere according to technological conditions and current developments. These directives serve as a working basis enabling the trade board to form an opinion on the various plants. Representing tolerance values of concentrations and precipitations of dust and gases, they make it possible to revise, at a given time, the values laid down by existing standards and to adapt them to more progressive methods. This is regarded as a decisive advantage over the procedure prevailing in other countries where emission limits are fixed by law.

It should be emphasized that the directives, which have just been published, are to be *applied to new plants*; the explanatory forms are uniform for all industries involved and give some introductory clues regarding the technique of the method.

A second section deals with the *reduction of dust emissions.* It is pointed out that dust production may be reduced by structural and operational measures, and special consideration is given to factors which either favour or hamper dust emission. To help choose the *most suitable dust collectors* the results obtained with standard or proven separators are indicated together with their main technical data as e.g. total dust removal efficiency, outlet dust loading, pressure drop, etc. In addition, those factors are indicated which increase or decrease the dust removing capacity of the collector, and the way dust emission is effected by stack height is shown.

The last section contains *directives and explanatory notes regarding the reduction of dust-like emissions.* The trade board will reserve the right to control proper observance of the limit values.

AIR POLLUTION IN SOUTH AFRICA. THE DEVELOPMENT OF PUBLIC OPINION ON THE SUBJECT

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SUMMARY: Interest in air pollution in South Africa began in 1948, but public opinion was not sufficiently strong to support expenditure. London " smog " of 1952 and an abnormal " smog " in Durban recreated interest. Council for Scientific and Industrial Research organized a national conference. Lectures and talks have been given by scientists working on air pollution. Public opinion is demanding controls on emissions from industry. When domestic smoke is dealt with a new type of education will be necessary.

Public interest in air pollution in South Africa began in 1948 with an article in the S.A. Engineer " Darkening Africa: the Problem of the Smoke Nuisance " and another in the magazine Municipal Affairs, " Tolerance of Atmospheric Pollution Inflicts Injuries on the Community " by Sir George Elliston[1, 2]. The Liaison Officer of the Council for Scientific and Industrial Research in Washington produced an excellent survey of the air pollution situation in America and this was the basis for further articles in industrial magazines as shown in the references.[3, 4, 5] These informative articles caused interest in the newspapers, with one or two feature articles and a number of letters from correspondents and were partly responsible for the City Council of Johannesburg appointing a " Smog Committee " which met regularly for about a year from 1950 to 1951. Public opinion at that time considered that South Africa with its sun and its wide open spaces, could not possibly suffer from air pollution, and though thoughtful people could recognize the steady increase in smokiness of Johannesburg and the neighbouring mining towns public interest was not sufficiently strong for the City Council to feel that it could spend public funds on a study of the position and the meetings of the committee ceased.

The London Fog of 1952 re-kindled interest in the question of air pollution and in 1954 the Federated Chamber of Industries, at its annual convention in Johannesburg debated a motion on " Control of harmful vapours, gases, effluents and other discharges " and decided that industry should actively support the formulation of legislation for the control of such effluents, as it was to the advantage of industry to see that such control was on the one hand effective, and on the other hand reasonable. At about the same time the National Council of Women, at its annual conference passed a resolution asking that steps should be taken to reduce air pollution in the cities, and sent it to the Minister of Health.

Up to this point the development of public opinion on the problem of air pollution had proceeded in an irregular fashion with occasional bursts of activity, but no clear opinion was observable. Then a crisis situation in Durban, the large seaport and holiday resort of Natal, to which thousands of people from Johannesburg flock for their holidays in the winter, brought the air pollution situation home to the public very forcibly. A few weeks of abnormally stagnant conditions in an atmosphere which is often stagnant caused visibility at midday to shrink to a matter of yards and made air pollution the subject of discussion throughout South Africa.

At about this time the National Physical Research Laboratory and the National Chemical Research Laboratory of the Council for Scientific and Industrial Research decided that the investigation of air pollution was a national concern and that steps should be taken to conduct research into some aspects of the problem. It was realized that in this very public matter, research and public education went hand in hand so that the first step taken was to organize a national conference on air pollution and to invite to this conference, representatives of all the larger city councils, chambers of commerce, chambers of industry, the railways, the chamber of mines, public health departments and civic vigilance organizations. This conference discussed the industrial, the legal and the scientific aspects of air pollution was well as its biological effects and it was well reported in the press throughout the country. The next step was to arrange for the formation, by the Minister of Health, of a National Committee on Air Pollution and for the commencement of a simple programme of pollution measurement in Pretoria, the administrative capital of the Union of South Africa, with a view to demonstrating to the public exactly what was the concentration of pollution being experienced in the city. The fact that measurements were being made attracted newspaper attention and from the commencement of these studies newspaper comment on the subject of pollution and the progress of the study of it has been regular and fairly widespread throughout the country. The scientists concerned with the study have been able to speak to the public from time to time and stress the important facts about air pollution so that the general public may now be said to be " smog minded " and definitely ready for some form of national action to reduce the emission of pollution. The National Physical Research Laboratory has itself undertaken a programme of public education but has addressed itself to the administrative groups such as health officials, municipal engineers, city councils and similar groups.[6, 7] These lectures usually receive newspaper coverage so that information about the nature of air pollution, its harmful effects and ways of reducing it, is regularly being widely spread. South Africa is still in the position that there are no effective legal provisions by which the emission of pollutants may be controlled and so an informed public is still a little helpless and restive, but city health authorities have been helped in their efforts to abate smoke nuisances by the existence of a strong public opinion that smoke at least, is undesirable. The results of the educational activity described above can be seen as far as industry is concerned, in the increasing number of inquiries which are received by the National Physical Research Laboratory, asking for information on the means for the reduction of, smoke from stacks, sulphur dioxide from certain industrial activities, dust from cement factories and acid vapours from some chemical processes. In addition, one large chemical industry is at present drawing up a code of practice for the control of emissions from its various factories and has asked the National Physical Research

Laboratory for advice on the effectiveness of the code. It can thus be said that public opinion is demanding controls on the emissions from industry and that industry is already considering the situation favourably. The smoke from domestic fires of all types is of course at present unrestricted and it is certain that when attempts are made to reduce this smoke—which accounts for about 50 per cent of the smokiness of the cities—a new type of education will have to be undertaken. This will be directed towards convincing the citizen that he also has a responsibility for clean air even if it does cost him something.

The question of national legislation for the control of the emission of pollutants is still under discussion but it is to be expected that any such legislation must include a policy of public enlightenment, explaining the value of alternative fuels to coal and encouraging householders to face the change to a new fuel willingly and co-operatively. The Council for Scientific and Industrial Research will increase its research programme and its informative talks in popular language on the results of the research so that this will continue to act as a stimulation of public interest in the reduction of air pollution. Experience in South Africa has shown the public are very receptive to clear statements about the results of research and are very willing to take action when they are given adequate information and reasons for the technical measures which should be taken.

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PUBLIC OPINION AND EDUCATION IN JAPAN

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SUMMARY: Their activities in the fields of information and research are listed. Other educational activities for abatement of pollution found in each community are given including such activities as refresher courses for boiler men, lecture meetings and film shows. Some communities are considering the institution of Smokeless Areas and are issuing Pollution forecasts. Public opinion and the press have both shown increasing interest in air pollution problems. The National Institute of Public Health undertakes the education of Health Education Officers. The establishment of a comprehensive organization for the prevention of Air Pollution is now being planned. Japanese Academic societies are also showing considerable interest.

Activities for making the public understand air pollution abatement methods and for securing their adoption are undertaken mainly by the commissions for the prevention of air pollution.

Their activities include: to answer inquiries from administrative agencies; to make recommendations or give advice about air pollution abatement; to undertake research into the real state of air pollution in the respective areas and make public the results; and to let people know the degree of pollution in their surroundings in order to build public opinion against air pollution.

It is noteworthy that the volume of falling soot is now on the decrease in industrial districts such as Kawasaki-Shi, Amagasaki-Shi, and Ube-Shi, where air pollution has hitherto been greatest.

Other activities for abatement purposes found in every community are: advice on the improvement of preventive facilities; refresher courses for boilermen; lectures and seminars; study meetings; a Smoke Prevention Week; and the showing of informative films. Some communities are blueprinting the institution of smokeless areas and are issuing pollution forecasts in co-operation with the meteorological observatory.

Public opinion has become interested in air pollution in the past few years, and especially in the Press there is a growing tendency to highlight the problem of air pollution.

The National Institute of Public Health takes charge of the education of health technical officers. Lectures on air pollution are given to Medical Officers of Health and Sanitary Officers in order to improve the health administrative officers' knowledge on this problem.

The establishment of a comprehensive organization for the prevention of air pollution during the present year is now being planned. The interested academic circles of hygiene, meteorology, physics, chemistry, architecture, and mechanical engineering, and the administrative agencies concerned are to be represented in this organization.

In the interested academic societies several results of investigations into air pollution have been made public since 1950. The Public Health Association of Japan has annually held a symposium on air pollution since 1956. It may be worth mentioning that the 1959 convention of the Japanese Medical Society conducted a symposium on public nuisances for the first time in Japan, taking up air pollution, as one of the items of discussion.

LEGISLATION IN JAPAN

The Institute of Public Health, Tokyo, Japan

SUMMARY: No general law has yet been enacted in Japan for prevention of Air Pollution, but Public Opinion increasingly demands such a law. In the meantime local governments have passed their own ordinances. These are divided into two categories, the first of which deals with the prevention of public nuisance in offices and workshops, and the second, which applies to Tokyo, deals with the public nuisance caused by smoke other than that produced in workshops. A table is given showing the administration and organization of these ordinances. Figures are also given for the budgeted costs for 1959.

Principles and Form of Legislation

In Japan we have, as yet, no enacted law for prevention of air pollution. The Welfare Ministry drafted in 1955 a Bill of Standards for prevention of atmospheric pollution, but it was not submitted to the Diet.

Public opinion demanding the enactment of such a law, however, has recently become louder than ever, as the air pollution in larger cities and industrial communities has become more conspicuous. In view of this situation, the Government is preparing for its enactment. Meanwhile, local governments, including Tokyo-To, Osaka-Fu, Fukuoka-Ken and Kanagawa-Ken, already have their own ordinances for air pollution abatement, and some other communities have competent commissions for this purpose consisting of administrative agencies and learned or experienced people.

Local ordinances for air pollution abatement are divided into the following two gategories:

(1) *Ordinances for prevention of public nuisance in offices and workshops—in Tokyo-To, Kanagawa-Ken, Osaka-Fu, and Fukuoka-Ken.*

An ordinance of this kind orders proprietors to take necessary steps for prevention of public nuisance and/or makes them remove an existing public nuisance according to complaints brought by the people affected.

(2) *Smoke abatement ordinance—in Tokyo-To.*

This controls the public nuisance caused by smoke other than that produced in workshops. The area of Tokyo is divided into two districts for this purpose, and smoke produced in each of them is regulated in accordance with the respective standards by means of Ringelman Chart No. 2 or No. 3.

Although both of the above ordinances prescribe examination on the spot by the officials concerned, which may be followed by warning and penalty, guidance and advice is as a rule preferred.

Administration and Organization

The administrative set up for this purpose is shown in the following table. The table shows whether each local government has the ordinance or not; the responsibilities of the bureau or division; organization and duties of the commission supplementary to the competent agencies; lower administrative institutions; and private organizations.

Cost

The 1959 appropriations are as follows. These amounts do not include personnel expenditure. The Prefectures are those having the ordinance for the purpose while the cities are those carrying on the business without ordinance. The amounts with the mark * contain expenses for the prevention of public nuisance, the others being appropriated only to air pollution abatement.

Local Government	1954 *Appropriation* (1,000*s Yen*)
Prefectures:	
Tokyo-To	4,000*
Kanagawa-Ken	2,000
Osaka-Fu	1,400*
Fukuoka-Ken	2,200
Cities:	
Amagasaki-Shi	1,500*
Sapporo-Shi	940
Kobe-Shi	1,100
Ube-Shi	1,000
Osaka-Shi	1,700

Table

	Prefectures				Cities				
Local Government	*Tokyo-To*	*Kanagawa-Ken*	*Osaka-Fu*	*Fukuoka-Ken*	*Sapporo-Shi*	*Osaka-Shi*	*Amagasaki-Shi*	*Kobe-Shi*	*Ube-Shi*
Ordinance	Yes	Yes	Yes	Yes	—	—	—	—	—
Competent Agencies:									
Public Nuisance ...	Housing Dept.	Commerce & Industry Div.	Commerce & Industry Div.	Health Dept.	—	—	—	—	—
Air Pollution ...	Health Dept.	—	Health Dept.	—	Waste Disposal Div.	Health Dept.	Health Dept.	Construction & Health	Health Sec.
Commission	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Consists of	Qualified Advisers (X) Officials (Y), & Assemblymen (Z)	X & Y	X, Y & Z	X, Y & Z	X, Y & Z	X & Y	X, Y & Z	X & Y	X, Y & Z
Duties	Liaison, Research & Judgment	Research, Investigation & Judgment	Judgment	Judgment	Research & Investigation	Liaison	Research, Investigation & Judgment	Research & Investigation	Research & Investigation
Lower Institutions (Health Centres)	Smoke Inspection	—	—	—	—	Smoke Inspection	Smoke Inspection	Smoke Inspection	Smoke Inspection
Co-operative Organization (e.g. Heat Control Ass., Chemical Soc.)	Yes	—	—	Yes	—	Yes	Yes	Yes	Yes
Private Organization...	—	—	—	—	—	Yes	Yes	—	

THE CONTROL OF AIR POLLUTION IN CANADA

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SUMMARY: There is no federal air pollution legislation in either the United States or Canada. In Canada air pollution control is largely a provincial responsibility, with the exception of vessels and railways. The Regulations made by some of the provinces are described, together with the rules of the Los Angeles Air Pollution Control District. The present trends in Canada are towards the adoption of the American Society of Mechanical Engineers' code of dust emission. There is also a trend towards oil and natural gas in industry, railways and vessels.

Introduction

In both Canada and the United States the control of air pollution is exercised on the local and provincial or state levels. There is no federal law in either country providing specifically for the control of atmospheric pollution from industrial sources. The British Clean Air Act, 1956, has no counterpart in either Canada or the United States; only in special situations arising out of pollution that involves transboundary flow from one country to another along the international boundary is it possible to invoke federal authority. Usually, such cases have been referred to the International Joint Commission for arbitration and settlement. Canada and the United States have been involved in two cases of this nature to date. The first related to pollution and damage to vegetation and property in the State of Washington during the late 1920s and the early 1930s from activities of the Consolidated Mining and Smelting Co. at Trail, B.C., about 10 miles from the International Boundary[4, 5]. The second problem is of comparatively recent origin and concerns transboundary air pollution in the Greater Detroit-Windsor area, arising from industrial and other activities, principally smoke, from the large volume of Great Lakes vessel traffic through the Detroit River.[8]

In Canada, therefore, the control of air pollution from industrial and other activities of the population is primarily a provincial responsibility except for emissions from combustion equipment of vessels plying navigable waters and from that of railways engaged in interprovincial or transcontinental transportation. The Railway Act, a federal measure, confers on the Board of Transport Commissioners for Canada, control of the activities of the railway systems crossing provincial boundaries. Regulations have been issued by this board governing the emission of smoke from locomotives and other railway installations.

Through the Canada Shipping Act, the Federal Government exercises control of vessels on all navigable waters within its jurisdiction. The Act authorizes the Governor in Council to make regulations governing the emission of smoke from vessels in Canadian waters, including the Canadian portion of the Detroit River, without conflict with the powers of the Provinces or local municipalities. To date, no such orders have been issued.

Province of Ontario

The control of air pollution is the responsibility of the provinces, except in the case of vessels and railways as cited above. Until recently, the Ontario Municipal Act contained enabling legislation whereby municipalities could pass by-laws to control the emission of smoke and other products of combustion within their boundaries. Recently, the sections of the Municipal Act dealing with air pollution were repealed and the Air Pollution Control Act, 1958, was passed. This Act became effective on May 21, 1958. It gives broad powers to municipalities to prohibit or regulate emission of air contaminants from any source. An Air Pollution Control Branch has been established in the Ontario Department of Health to furnish advice in the field of air pollution, to assist municipal officials in the preparation of air pollution control by-laws, in development of air pollution control programmes, and in training of local staffs for this purpose. Authorization is given to investigate or make arrangements for investigation of air pollution problems.

The Ontario Public Health Act deals with a variety of public health problems. Sections 80 to 89 inclusive of the Act deal with nuisances which include those due to air pollution. Section 80 defines a nuisance as follows:

> Any condition existing in any locality which is or may become injurious or dangerous to health or prevent or hinder in any manner the suppression of disease shall be deemed a nuisance within the meaning of this Act. R.S.O. 1950, c. 306, s. 80.

The provisions of the Act relative to air pollution problems are not enforceable unless it can be shown that the pollution is injurious or dangerous to health. In practice, medical officers of health have not undertaken air pollution control work under the terms of the Act.

One further legal device available to the province may be mentioned. Under the Sulphur Fume Damage Arbitration Act, an arbitrator, acting under the Ontario Department of Mines, may appraise damages and assess penalties in such cases as injury to agricultural and forest species by sulphur fumes from smelting or refining of nickel, copper or iron ores.

The provisions of the Ontario Air Pollution Control Act, 1958, that are of direct concern to municipalities are as follows:

Section 1—*Subsection* (2)

> The density of an air contaminant that is approximately black shall be determined by means of a chart commonly known as the Ringelmann Chart, a Micro-Ringelmann Chart, or by a comparable chart having black dots upon a white ground, or by a glass comparator, so as to produce:
>
> No. 1 density—approximately 20% black with approximately 80% of the ground white.
>
> No. 2 density—approximately 40% black with approximately 60% of the ground white.
>
> No. 3 density—approximately 60% black with approximately 40% of the ground white.
>
> No. 4 density—approximately 80% black with approximately 20% of the ground white.
>
> No. 5 density—approximately 100% black.

Subsection (3)

> The density of an air contaminant to which subsection 2 does not apply shall be determined

by its opacity by means of visual inspection thereof and shall be related to the density of an air contaminant under subsection 2 that has approximately the same degree of opacity.

Section 3—Subsection (1)

The council of any municipality may pass by-laws for prohibiting or regulating the emission from any source of air contaminants or any type or class thereof.

The Ontario Act provides that a proposed by-law under Section 3 shall be submitted to the Minister of Health for review and advice during a thirty-day period prior to passage. Section 5 provides that any two or more municipalities may enter into agreement to provide for joint administration and enforcement of their respective air pollution control by-laws and to provide for the sharing of the cost thereof.

Under Section 6 of the Act, the Minister may, with the approval of the Lieutenant-Governor in Council, make regulations for prohibition or control of emission of air contaminants from any source, applicable in territory without municipal organization. Such regulation may be general in its application or may be restricted to any designated, specific area or class of premises.

Other Sections of this Air Pollution Control Act contain provisions for regulating the construction, installation, repair, and usage of any combustion or other equipment or structure from which any air contaminant may be emitted; and for requiring that plans and specifications and any other information therefor, as required, be filed with and approved by a municipal officer in incorporated areas or by a provincial officer in territory without municipal organization. It is also stipulated that such work, installation or structure must be inspected when completed and a certificate issued that the work complies with the plans and specifications filed and with the air pollution by-law of the municipality prior to the operation or use of such equipment, device or structure. Provincial officers may enter and inspect any premises and conduct tests or make examinations as may be necessary for the purposes of the Act and the council of any municipality may pass by-laws to authorize municipal officers to do likewise. A municipal officer may be granted the authority, under the council of a municipality, to permit deviations from the requirements of any air pollution control by-law.

Municipal By-Laws for the Regulation of Air Pollution

Such organizations as the U.S. Bureau of Mines, the American Society of Mechanical Engineers, the Air Pollution Control Association (Pittsburgh), and the Los Angeles County Air Pollution Control District have had a marked influence on the extent to which various contaminants from vents or stacks such as smoke, dust or fly-ash, sulphur dioxide and other types of emissions may be prohibited or controlled.

Regulations passed in May 1957 by the Municipality of Metropolitan Toronto prohibit the discharge to the atmosphere of smoke, dust, fly-ash, soot, fumes or other solid or gaseous products of combustion, the shade or appearance of which is equal to or greater than No. 2 on the Ringelmann Smoke Chart, for a period of or periods aggregating ten minutes or more in any one hour. It is also prohibited to discharge such contaminants at a density equivalent in shade or appearance to or greater than No. 3 Ringelmann for a period or periods aggregating six minutes in any one hour. Furthermore, no person shall cause, suffer or allow to be discharged from any fuel-burning equipment, internal combustion engine or vehicle, or from any premises such contaminants, as mentioned above, to an extent that is detrimental to the property of any other person or that is a nuisance to any person.

Other provisions of the Toronto by-law prohibit the discharge of any dust, soot or fly-ash exceeding 0·85 pounds per 1,000 pounds of gases, adjusted to 12 per cent CO_2 content. Where installations of dust collection or separating equipment become necessary, the efficiency of collection must not be less than 85 per cent, so that not more than 15 per cent of the total dust, soot or fly-ash entering such equipment would be discharged into the atmosphere. It is stipulated that the amount of such dust in the flue gases shall be determined according to the Test Code for Dust-Separating Apparatus of the American Society of Mechanical Engineers. All fuel-burning equipment in which pulverized fuel is burned or in which spreader stokers, or similar equipment is installed, must be provided with dust-separating equipment.

The Metropolitan Toronto by-law also contains clauses relating to a requirement for increasing the height of existing stacks and chimneys to abate a nuisance to occupants of any building or structure subsequently erected. There are included in this by-law the customary provisions for the issuance of installation and operating permits for fuel-burning equipment, inspection of premises and equipment, investigation of complaints and study of smoke conditions.

The regulations of most other cities and towns in Ontario that have passed by-laws to control air pollution contain similar features to those of Toronto, except for minor modifications. Since proposed new by-laws to control air pollution will have to be submitted to the Ontario Minister of Health for review and advice, prior to adoption, in order to insure conformity with the Provincial Air Pollution Control Act, 1958, it is anticipated that municipal regulations will become uniform in nature in the future.

The township of Trafalgar, Ontario, has enacted air pollution control regulations directed specifically towards oil refining operations located within the township. These contain some unique features as influenced by the provisions of regulations in the by-laws of the Los Angeles Air Pollution Control District. In addition to the usual prohibitions against emission of excessive smoke from furnaces, flares and combustion equipment, the Trafalgar by-law limits the discharge of dust from a catalytic cracking unit, based on the handling of 7,000 barrels of feed intake per day, to an average of 30 tons per month or one ton per day (about 83 lb. per hour). The emission of sulphur dioxide from any process unit stack is limited by the maximum ground concentration which must not exceed a top limit of 0·5 parts per million in air, by volume. To meet this limitation on the discharge of sulphur dioxide, stacks, chimneys, or flares handling products of combustion that contain major amounts of sulphur dioxide must be adequately designed to provide sufficient effective heights to disperse the waste gas under a wide variety of meteorological conditions.

Other clauses in the Trafalgar by-law provide for the installation of conservation or floating roofs on oil storage tanks, for covering A.P.I. oil-water separators up to the first oil retention baffle, and for the suppression of vapour losses generally from pressure relief vents, valves, product storage tanks, loading and filling operations. Here, again, the insertion of these clauses in the by-law has been based on the experience and reports of the Los Angeles Air Pollution Control District.

Other Provinces of Canada

Preliminary steps have been taken to control air pollution in Manitoba by the drafting of suitable regulations relating to emissions from various types of fuel-burning equipment. It is likely that the provincial act, when passed, will bear considerable resemblance to the provisions of the Ontario act.

A special arbitration act passed by the Manitoba Government in 1957 deals with the emissions of waste products from the Manitoba mining and smelting industry.

In other provinces of Canada, the control of pollution is left largely at the local level. There are no provincial acts directed specifically to air pollution control. Such powers as may be delegated to municipalities are derived under either provincial health or municipal acts.

Los Angeles A.P.C.D. Rules

In view of the widespread publicity that has been given to the troublesome Los Angeles air pollution problem, the regulations enacted in Los Angeles county, although designed to deal with the local situation, are likely to influence future control activities in many other areas of North America. However, few if any other industrial areas in the world have the unfavourable meteorological and topographic factors that produce the prolonged temperature inversions and smog of the Los Angeles type. The distinctive features of this smog are eye irritation, reduced visibility, accelerated cracking of rubber goods and extensive damage to vegetation[2, 3]. The smog is characterized by the presence of relatively high concentrations of oxidants or ozone, aerosols, oxides of nitrogen, hydrocarbons and other organic compounds.[6] The major sources of pollution, apart from industrial operations which are very strictly controlled as to emissions, are considered to be the exhaust gases from more than 2·5 million motor vehicles operating in the county. There is no solid fuel used in the Los Angeles District and only "smokeless" liquid or gaseous fuels are permitted.

The rules and regulations[7] prohibit the discharge into the atmosphere of the following contaminants in amounts greater than the designated permissible limits:

1. Any emission of air contaminants for more than 3 minutes in any one hour which is as dark as or darker than that designated as No. 2 on the Ringelmann Chart or which has an opacity sufficient to obscure an observer's view to the same extent as does smoke designated as No. 2 Ringelmann.
2. The discharge of any contaminant which would constitute a common law nuisance, or cause injury to the public, or damage to business or property, or cause detriment, injury or annoyance.
3. The discharge from any source of particulate matter in excess of 0·4 grain per cu. ft., at the standard temperature of 60°F and pressure of 14·7 lb. per sq. in.
4. The discharge of solid products of combustion in excess of 0·4 grain per cu. ft. of gas calculated to 12 per cent of carbon dioxide content.
5. The discharge of sulphur compounds calculated as SO_2 in excess of 0·20 per cent by volume at the point of discharge.
6. The emission of dust or fumes in excess of that determined in accordance with a sliding scale based on process weight of materials used in any specific process (except liquid or gaseous fuels and air), as follows:

Process wt. lb./hr.	*Maximum wt. of discharge lb./hr.*	*Efficiency of dust recovery per cent*
50	0·24	99·52
100	0·46	99·54
500	1·77	99·65
1,000	2·80	99·72
2,000	4·14	99·79
5,000	6·67	99·87
10,000	10·0	99·90
20,000	16·19	99·92
60,000 or more	40·0	99·93+

With reference to Los Angeles test standards, all analyses and tests shall be calculated or reported at the standard gas temperature of 60°F and the standard pressure of 14·7 lb./sq. in.

Permits are required by any person building, erecting, altering, replacing or operating any machine, equipment or other contrivance the use of which may cause the emission of air contaminants. It is also stipulated that such permits shall not be granted unless it is shown that the equipment is so designed or controlled, or so equipped with air pollution control devices, that with proper supervision and use it may be expected to operate without the emission of air contaminants in violation of the Rules of the Los Angeles Air Pollution Control District.

A recently enacted regulation (Rule 62) prohibits the burning of liquid or solid fuels having a sulphur content in excess of 0·5 per cent by weight and the burning of gaseous fuels containing sulphur compounds in excess of 50 grains per 100 cubic feet, calculated as hydrogen sulphide, from May 1st to October 31st of each year. Steam-electric generating power plants are the largest industrial consumers of both fuel oil and natural gas in Los Angeles county. Such plants consume more than twice the quantity of fuel oil used by all other industrial users and approximately ten times as much fuel oil as that used by the oil refineries.

In the United States as a whole, although, as mentioned previously, no federal legislation relating to control measures has been enacted, the passage in 1955 of the Federal Air Pollution Research and Technical Assistance Act (Public Law 159—84th Congress) has resulted in a measure of progress with respect to consultative services and enlargement of research activities.

Canadian Trends in Air Pollution Control

In Canada, air pollution control regulations and standards of emission may become more stringent in the future but are not likely to approach the relatively severe limitations imposed in the Loss Angeles area. In the case of smoke emission from fuel-burning equipment, most of the municipal ordinances prohibit the discharge of No. 2 smoke or darker shade on the Ringelmann chart, except for specified, limited periods in any one hour or fraction thereof. The emission of other visible contaminants, apart from smoke, may be regulated by an opacity clause which is equivalent to the obscuration of an observer's view of the stack discharge to an extent equal to No. 2 Ringelmann. This may cover the emission of sulphur trioxide or sulphuric acid mist, oxides of nitrogen, and other products of combustion or chemical fumes, mists or gases.

Thus far, there are only two areas in Canada where limitations have been imposed directly on the discharge of sulphur dioxide. These limitations involve in one case a Convention between Canada and the United States which prohibits the smelter at Trail, B.C., from discharging sulphur dioxide in any amount that may result in a maximum ground concentration of 0·30 p.p.m. during the growing season, or 0·50 p p.m. during the non-growing season, for a period greater than about one hour, at any point beyond the international boundary in United States territory.[1] The second case is that of sulphur dioxide from oil refining process units in the township of Trafalgar, Ontario, under By-Law No. 1957-50, mentioned previously.

With reference to the regulation of the emission of dust or fly-ash from fuel-burning equipment, the trend is to adopt the relevant clause in the model ordinance of the American Society of Mechanical Engineers which provides that the dust loading of stack gases shall not exceed 0·85 lb. dust or fly-ash per 1,000 lb. of gases adjusted to 50 per cent excess air (or 12 per cent CO_2 content). To this may be added a stipulation that would prohibit the emission from a stack of more than 15 per cent of the total dust measured at the point of entry to a collection device. The 15 per cent restriction on dust emission makes an ordinance of this type more severe than the ASME model, since, in some cases, the dust loading in the stack may have to be reduced below the 0·85 lb. per 1,000 lb. limit to comply with this other provision.

The above restrictions on dust or fly-ash discharged to the atmosphere along with smoke emission limitations tend to make it more difficult to utilize bituminous coal as fuel, especially when it contains upwards of 8 to 12 per cent of ash. Additional control facilities are required to handle solid fuel consumption, especially in the range of 1,000 to 5,000 tons or more per day in large installations for industrial steam plants or for generation of electric power. The dust collection or precipitation equipment to recover and dispose of the resultant fly-ash adds to the capital cost of plant construction and increases the price of such fuel in contrast to relatively "smokeless" fuels such as oil or natural gas, which can meet air pollution control regulations without the necessity for installation of dust recovery systems.

Rapid progress is being made in the dieselization of the railway systems of Canada. Eventually, coal-burning locomotives will be replaced entirely by diesel locomotives in freight, passenger and yard switching operations. The Board of Transport Commissioners for Canada have recently revised their air pollution and smoke control regulations for railway companies subject to the jurisdiction of the Board in the new General Order No. 838, dated February 2, 1959. The regulations apply only in municipalities that have passed or may hereafter pass by-laws for the regulation, control or prohibition of smoke or other air pollutants and that employ a municipal officer to enforce such by-laws. In the above Order of the Board, it is not permissible to discharge smoke of a density greater than No. 2 of the Ringelmann Chart from coal-burning locomotives in service or ready for service, except that a density equal to but not greater than No. 3 will be allowed for a period or periods aggregating not more than 90 seconds in any one 10-minute period. In the case of oil-fired diesel locomotives the restriction on smoke emission is more severe and the limitations are No. 1 and No. 2 Ringelmann for comparable locomotive operations. Other clauses in the order contain prohibitions on smoke emission of specified densities from other railway equipment, internal combustion engines, locomotive repair shops, incinerators and other property.

The trend towards oil-burning equipment in place of coal-fired furnaces is also evident in vessel transportation on the Great Lakes and St. Lawrence Seaway system. A report submitted recently by a Technical Advisory Board to the International Joint Commission[8] deals comprehensively with the results of an extensive study of air pollution in the Detroit-Windsor area, including the problem of excessive smoke emission from Great Lakes vessel traffic on the Detroit River. With regard to air pollution from vessels, the findings indicate that hand-fired coal-burning vessels contribute seriously to the pollution problem. The most satisfactory control of air pollution is exercised by vessels equipped with oil-burning furnaces or diesel engines. It is estimated in the above Report that approximately 250 hand-fired vessels would have to be converted to either stoker or oil firing to meet reasonable smoke emission standards.

The Recommendations of the above Technical Advisory Board provide for the adoption by the Governments of Canada and the United States of a code prescribing limitations on the emission of air pollutants from vessels in the Detroit River and set standards for their measurement. It is proposed that all vessels, except small hand-fired cargo vessels with a gross cargo-carrying capacity of 3,200 short tons or less (canalers) be put under a smoke limitation code that is equivalent in its provisions to the Model Smoke Ordinance of the American Society of Mechanical Engineers. A more lenient regulation is proposed for the small canaler class of cargo vessel mentioned above, but its exemption would be removed two years after the official opening of the St. Lawrence Seaway or at such later time as the two Governments shall determine that such action would be in the best interests of Canada and the United States.

There is no doubt that such recommendations, if adopted by the Governments of Canada and the United States, would have a profound influence on the nature of fuel-burning equipment installed on vessels operating in the St. Lawrence Seaway. Eventually such air pollution control regulations would lead to the conversion of all hand-fired vessels to either oil-firing or some form of automatic stoker firing for solid fuel.

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II. 11

SOME ACTIVITIES IN BELGIUM IN THE FIELD OF ATMOSPHERIC POLLUTION DURING THE LAST FIVE YEARS

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SUMMARY: More attention has been paid to air pollution in Belgium since the Meuse valley fogs of 1930. The Belgium Town Planning Administration has commissioned an air pollution study of the Liege region, as part of a general planning survey of the region. A number of experts have undertaken other studies and published results.

Introduction

While the question has been neither neglected nor lost sight of by us, the fact is that the attention of investigators in the field of atmospheric pollution has been particularly drawn to this subject since the famous Meuse river fogs of 1930.

The inquiries set on foot after these incidents gave rise to many studies, both on the mechanism of evolution of products discharged into the atmosphere and on the control of the degree of pollution of streams and air in industrial and urban districts.

During the last few years extensive inquiries were decided upon on the initiative of the Ministry of Public Works (Town Planning Dept.) while complaints lodged with the authorities in respect of certain industrial nuisances contributed to an increase of investigations into the nature of the atmospheres in question, both before and after introducing measures for combating the emissions. These studies are briefly surveyed in the following pages, but we do not claim to cover all the research undertaken during this period in Belgium.

Investigations decided on by the Town Planning Dept. (Ministry of Public Works), in the Liege District, including the Industrial Suburbs

The Belgian Town Planning Administration (Director General Mr. Bure) instructed Messrs. Fitschy, Klutz, Parent and Tibaux, of the Architectural and Town Planning Office " L'Equerre ", to draw up a plan covering the Liege region.

In this connection an important place has been reserved for the general state of the atmosphere and the industrial activities of the region which, as already mentioned, comprises many iron and steel mills.

This general study of the atmosphere and its consequences has been entrusted to:

Mr. Edm. Leclerc, for chemical studies of the atmosphere,
Mr. L. Poncelet, for meteorological questions,
Messrs. P. Heinemann and A. William, for examination of the damage to plants,
Drs. J. Firket and Legros, for its effects on human health.

The beneficent part played by plants as a factor of air purification has been studied more particularly by Profs. Bouillenne and William.

As regards a thorough study of the industrial activity of the district, this was undertaken by Mr. J. A. Sporck, who was advised by Messrs. M. Tulipe and Delmer.

A summary of this investigation is given in the article by Mr. E. Parent, published in: Revue Universelle des Mines, special Atmospheric Pollution issue, May 1954, Series 9, Vol. X, No. 5, p. 109.

The effects of atmospheric pollution are characterized by vitiation of the air breathed by man and animals, by specific action on plants and lastly by weathering of metals and minerals.

In a general way, the coarse and fine dust deposited in the streets and houses contributes to keeping them dirty and considerably increases the maintenance costs.

For certain businesses which require pure air, for industrial purposes or for storing delicate materials, it becomes necessary to filter the air, with consequent technical complications and appreciable expense.

The study of air pollution in the Liege region has made it possible to draw up relative pollution maps on the basis of two tests: the first relates to the weight of the dust deposited on the ground per unit of time and exposed surface, the second test measuring the sulphurous gases in the atmosphere.

By means of either test a relative degree of daily pollution can be expressed, thus permitting of comparisons between different stations equipped with measuring instruments.

The work so far done, for which a very large number of stations has been selected, from the Engis region to as far as Vise, shows how pollution varies according to different factors, viz.:

seasons,
average direction of winds,
position of the station on level or high ground,
effect of localized sources of industrial pollution,
effect of dumps, etc.

On the basis of all these results maps have been drawn showing zones affected by equal mean pollution, both by dust or gases. An abstract of this study with comments on the methods used and some of the results obtained, has appeared in: Rev. Univers. des Mines, December 1953, Series 9, Vol. IX, No. 12.

Some Scientific or Technical Papers on Atmospheric Pollution by Industrial Fumes

After a meeting held at Paris at the E.E.C.O. investigations were undertaken, particularly in Belgium, in order to compare the methods of measuring air pollution and establish procedures which would give comparable results in the different countries.

The Institute for Encouragement of Scientific Research in Industry and Agriculture (I.R.S.I.A.) has subsidized this work in Belgium in connection with which the air in different regions of the country will be analyzed.

Apart from this work, only recently decided on, other research work has been done in this country on the problem of air pollution in the industrial regions.

Without claiming to have exhausted the subject we can mention: Effect of Dusts and Fumes on Vegetation: Publications by the Botanical Institute of Liege (Prof. Bouillenne), by the State Agronomical Institute of Gembloux (Prof. William), by Ghent University (Prof. G. Verplancke). Effect of Fumes on individuals:

Publications of the Institute of Pathology (Prof. J. Firket).

Research on the meteorological and climatological aspects of atmospheric pollutions, by L. Poncelet (Royal Meteorological Institute).

Research on atmospheric corrosion, by Commission IV of the A.B.E.M. (see paper by R. Pourbaix on " Four Years of atmospheric corrosion tests in Belgium ".

Lastly, in a general way, our Institute of Industrial Chemistry (Dept. of Sanitary Technique) takes a constant interest in the nature of polluted atmospheres, in the various rates of incidence of these pollutions in the industrial and economic fields,[1] in the methods of measuring the degree of pollution in towns and built-up industrial areas.

Thanks to modern, highly sensitive processes we can now detect and measure trace elements in air, whether metals or oxides, traces of gas (fluorine), aerosols, hydrocarbons (benzpyrene), etc. Recourse to these techniques is now indispensible in all laboratories which are testing the condition of atmospheres and for appreciating the improvement due to the introduction of methods of purification or abatement of gases, dusts and aerosols.

Of course, apart from these scientific activities, a great deal of work has been done in factories to abate certain fume or dust nuisances. This work is being done direct by the concerns in question.

Without going into further details of the work done or planned, we might point out that our manufacturers are in touch with the foreign experts. In particular there are constantly missions being sent, and we in particular, were members of the E.E.C.O. Mission 136 to the United States.

The report on water and air pollution published by this body in 1957 interrelates the data collected in that country and Europe with the techniques applied in the control of air pollution in the iron and steel industry.

The meeting held in London in 1957 on water and air pollution in the iron and steel industry was attended by a Belgian delegation who followed its transactions.

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II. 12

ATMOSPHERIC POLLUTION PROBLEMS IN NORWAY

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SUMMARY: Atmospheric pollution in Norway has not been a serious problem in the past, but in the last few years fluorosis in cattle caused by air pollution and pollution of the grass with fluorides from aluminium industry has been of considerable public interest which has led to the appointment of a Committee on air pollution. The Committee is to investigate what can and should be done to prevent air pollution and eventually to recommend abatement laws and regulations. The 1958 report of the Committee contains suggestions for dealing with pollution problems. Although air pollution in Norway is not disturbing compared with other countries analysis of the measurements taken in recent years shows that it is a considerable nuisance. It is suggested that even more use should be made of hydro-electric power for domestic heating and so reduce even further the amount of pollution.

Atmospheric pollution in cities and industrial centres of Norway has not been considered a serious problem except on rare occasions like the manganese pneumonias of Sauda, an endemic of acute lobar pneumonias among the 4,000 dwellers of a small community in the bottom of a narrow valley at the western coast of Norway—the incidence approaching five times that of the population of Norway during several years. A very close correlation between the frequency of pneumonia deaths among the inhabitants of the small community and the production of ferromanganese and silicomanganese at an electrometallurgic plant in the valley during the years from the start of the production in 1924 through the years of economic depression to 1938,[1] points to the *atmospheric* pollution by manganese oxides as the most probable cause of the high endemic frequency of the disease, since the high pneumonia incidence was not confined to the plant employees, which seems to be the finding in most reported endemics of manganese pneumonias in the world literature.

In the last few years fluorosis in cattle, caused by air pollution and subsequently pollution of grass with fluorides from an aluminium industry in a similar topographic location as that described above, has been of considerable public interest, which caused the appointment of a committee on air pollution, " Roykskadekomiteen ", to investigate what can and should be done to prevent gases, smoke and dust from industries, etc., from becoming a health menace for man or animals or deleterious to plant growth; and eventually to recommend air pollution abatement laws and regulations. In the report of May 1958[2] the committee suggests, in short:

1. Appointment of a standing expert panel on air pollution problems.
2. (a) Introduction of a system of concessions pertinent to the development of new industrial plants and to changes in existing industry, when these are likely to increase the air pollution hazard.
    (b) Advancement, primarily on a voluntary basis, of the necessary air pollution abatement programme in existing non-expanding industry.
    (c) Any industry with an air pollution hazard (dependent on concession or not), shall be required to give information of importance for the abatement of such pollution, and if necessary the public investigators should be admitted.
3. Surveys of the general air pollution in Norwegian cities should be continued, to gain the necessary basic information for the abatement of air pollution in cities and dwelling districts. Adequate smoke abatement regulations should be introduced in the Housing law, and existing regulations in the law on motor vehicles, on the prevention of exhaust nuisance, should be enforced.

Action taken by the legislature along these lines are to be expected this fall in connection with the revision of our Neighbourship Law and our Housing law.

The most serious air pollution problems in Norway may arise from the fact that all other reasons but the air pollution hazard point to deep valleys at the coast of Norway as the best locations for several kinds of heavy industry. This position for an industry with

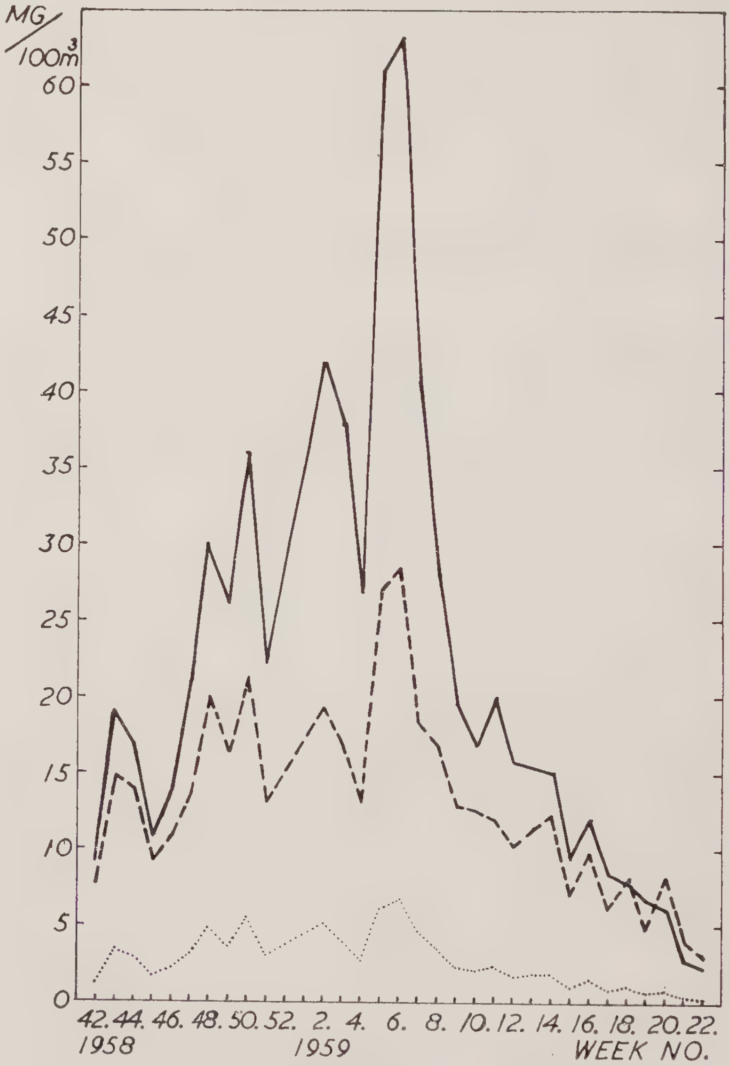

Fig 1

Air pollution measured at 11 *sites in Oslo. Weekly averages October* 1958 *to June* 1959 *in milligrams per* 100 *cu.m of air*

SO₂——— *Smoke* - - - - - - *Tarrymatter*...........

an air pollution hazard simply invites disaster.

Compared with the more densely populated countries in Europe, we should not expect the general air pollution in Norwegian cities and dwelling districts to be disturbing, since the cities are relatively small and separated by wide, scarcely populated areas. The results of a dust fall survey in Oslo (*ca.* 450,000 inhabitants) using 49 British Standard Deposit Gauges throughout 1956/57,[3] confirm, however, the public opinion that the dust fall in some parts of the city, at least during the winter, is a considerable nuisance. Compared with the average dust fall registered by 40 sampling stations in the London area in 1955, the amounts of total dust fall, and of ash and of combustible matter, averaged in the central zone of Oslo 55 per cent, in the middle zone 40 per cent, and in the peripheral zone 20 per cent of the average values found in London. At some sites the mean total dust fall in the year exceeded 1,000 g per 100 sq m per 30 days. A somewhat unexpected drop of the Oslo values in December is explained by a reduction of wind-generated dust during the snow-covered period, followed by a peak in April, when the snow melts, leaving the sand and gravel gathered through the winter. Without this effect of the snow-cover during the winter, the mean registered dust fall should most certainly have been found to be higher. The dust fall surveys of the following years in Oslo have confirmed these results.

Since October 12, 1958, the air pollution in Oslo has been registered[4] by employing the smoke filter and volumetric sulphur dioxide apparatus, recommended by Department of Scientific and Industrial Research, Fuel Research Station, London. At 11 selected sites the daily smoke values (by reflectometer readings), the daily sulphur dioxide values (by titration of total acidity following absorbtion in peroxide solution), and the daily "tarry matter" values (by fluorescence measurements—method not published), have been estimated. Fig. 1 shows the weekly averages October 1958 to June 1959 in milligrams per 100 cu m of air. The high sulphur dioxide values during the cold season are noteworthy. The comparatively smaller smoke values are in accordance with the widespread use of oil and other smokeless fuels in Oslo. The air pollution in Oslo seems to be characterized by:

1. A marked seasonal variation due to the cold winter and accordingly high fuel consumption for domestic heating.
2. Frequent accumulations of air pollutants during the winter in periods of calm weather and inverse vertical temperature gradient, the surrounding hills serving as a barrier.

From the public health point of view we are inclined to pay just as much attention to the high winter values as to the low mean value of the year. Ways of reducing atmospheric pollution in Oslo exist, since inexpensive supplies of hydro-electric power may be used for domestic heating, and a more extensive use of electricity for this purpose should be encouraged.

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II. 13

PUBLIC OPINION AND EDUCATION FOR CLEAN AIR IN THE UNITED KINGDOM

ARNOLD MARSH, O.B.E., Director, National Society for Clean Air, Great Britain

SUMMARY: The general question of creating an educated public opinion on air pollution and its prevention is discussed with particular reference to the United Kingdom and the work of the National Society for Clean Air. The work falls into two main categories—that directed towards the groups which themselves lead or create mass public opinion or are concerned technically or administratively with the problem, and the mass publicity that is called for when the community in general is directly affected by clean air legislation, for which considerable resources are required.

Although this contribution will refer in particular to the work that has been done and the difficulties that have been encountered in the United Kingdom, it is hoped that the principles to be indicated may be of interest to those concerned with similar situations in other countries.

Except in special circumstances the problems of air pollution in any town or conurbation grow slowly and insidiously, so that the inhabitants become accustomed to them and fail to notice gradually worsening conditions. Environmental standards, such as those of amenity and even cleanliness, become degraded, and like the weather, the drabness and unpleasantness of towns become accepted as natural and inevitable. The cleanliness of the countryside may be envied, but it is regarded as something peculiar to rural life.

Sooner or later, however, a more perceptive minority become conscious of the state of things, recognize the extent to which the polluted air is affecting the life of the community, and begin to demand that action should be taken to reduce or prevent it. In the conference brochure, *Sixty Years for Clean Air*, will be found an account of how this Society, then the Coal Smoke Abatement Society, began in London in 1899. It was formed by a tiny group of private people and with hardly any funds. Of necessity it began its work with a very limited programme—specifically, to encourage the local authorities to take action in cases of infraction of the law. There was no attempt, except perhaps, incidentally, to convert the public at large.

Perhaps, for the sake of overseas delegates, it should be made clear that the Society was, and still is, an organization of a voluntary nature—that is, it has no official status, and membership is open to all individuals, authorities and industries who accept its objects and who have equal rights as members in governing its policies and activities.

The task of creating or changing public opinion is too often regarded as a mass campaign to be addressed directly to the public, using the methods made familiar by commercial, Government, and other campaigns which have large funds behind them. This mass approach was not (and still is not) available to a small, penurious organization, except when its activities are of news interest to the popular Press.

What, however, a small independent organization can do, and which the Society has done, not without success, is to devote its resources of educating, informing and so influencing the opinion of the relatively small numbers of those who themselves create or lead public opinion. The Society has, therefore, directed the greater part of its efforts to establishing a favourable and informed opinion among the legislators and administrators, especially in local government, among technologists and scientists, in the medical profession, among the Press itself and those who write for it, and among teachers, lecturers and so on. Little by little, urged on by the Society, these have influenced others, so that, today, we are at last finding the emergence of a truly mass public opinion aware of the need, and ready to accept the necessary measures, for clean air. Even advocate specific limited actions, new legislation, etc., or to complain or criticize, has had a wider value than the ostensible purpose: such activity has always helped, directly or indirectly, to promote this influential opinion.

It may, however, be said that of greater importance than the slow nurturing of public opinion by the Society over the years, were the shock of the great London smog of 1952, the findings of the Beaver Committee which followed, and the new Clean Air Act. One does not wish to claim too much for the Society, even on this special anniversary, but it must be emphasized that the great smog crowned, and the Beaver Committee confirmed, the case that had been developed and pressed by the Society and its supporters; and that the Clean Air Act has been made possible and acceptable, and is working successfully, largely because of the climate of public opinion and the extent of practical knowledge that had steadily been built up by the Society during the past sixty years.

The recent advances in the United Kingdom do not mean that the Society's work in the field of public opinion and education is ending. On the contrary, it is developing into an important new phase. There is still the need to strengthen and consolidate and strengthen the understanding and support of influential opinion, and to guide and inform it throughout a period of continuing change. One of the purposes of this conference is to assist in this. But now, also, it is becoming urgently necessary to educate the millions of individuals who are being directly involved in the smoke control area programme. For the success of this much heavier task, which involves a continuing national campaign, much greater funds are obviously needed—which, so far, the Society does not enjoy or any one else is prepared to make available. By means of its information services, publications, loan exhibits, posters and meetings, the Society is aiding this slowly developing mass campaign, but only with difficulty and as yet to a comparatively small extent.

As mentioned earlier, one of the best ways in which publicity can be secured with relatively little cost is through the Press and the broadcasting and television services, but this requires a steady flow of activities which possess news value. It is, for example, hoped that the present conference will have some mass publicity, which even if it does not provide details will at least impress upon the many the simple fact that clean air is so important that it warrants an international conference in London.

Other forms of mass publicity require expenditure generally proportionate to the size of the field to be covered, although the methods that may be used call for careful study and experiment to determine which is likely to be the most economic. Unlike commercial publicity there are no sales returns to provide checks and comparisons. It is important also not to attempt too diffuse or ambitious a programme, but rather by calculated limitation, to concentrate and reiterate.

A problem in all publicity and educational work on a limited budget and not in itself bringing a financial return, is the need to compete for attention with commercial publicity. This is, for it is profitable for it to be, of a high standard of design and presentation, whatever its form. Though its message may be admirable, publicity which is cheap or amateurish will largely fail. Again, therefore, it is better to limit one's field and to have less first-class material than more which is second-class. This applies to printed matter of all kinds, from journals to posters and even stationery, as well as to exhibition materials and displays.

The subject matter of publicity and education also requires careful consideration. In brief, it must always be accurate, and while it should be forceful it should not alienate educated opinion by distortions. That intended for the better informed—the leaders of opinion—should itself be informative, and often detailed; that for the mass campaign should combine simple information with the simple slogan or attention-catching " lead." There are, of course, many other groups calling for their own special treatment, such as education in the schools, among women, in industry, and so on.

The purpose of the publicity, broadly, and at least in the United Kingdom, is two-fold; to make known the facts about air pollution, and to secure agreement on (or acceptance of) measures that must be taken against it. For the latter it is desirable to keep ahead, but not too far ahead, of informed opinion.

In other countries the problem may be different.

Our need in Britain for mass publicity arises because of our special problem of pollution from domestic coal fires. To a lesser extent similar mobilization of public opinion has been required in cities in the United States, and may well be necessary in other countries. With respect to pollution from industry and transport the support of public opinion may be necessary only to help to secure the passing of the control legislation and the enforcement of standards that are called for. Even if this is not necessary there remains the need to educate and convince the legislators and administrators themselves. This conference, with its many papers and discussions will, it is hoped, help towards that end by disseminating information to every part of the world where the problems of air pollution are causing concern.

II. 14

INVESTIGATIONS ON AIR POLLUTION IN BASLE (SWITZERLAND)

THEODOR MÜLLER, M.D., Chief Officer of the Public Health Office, Basle, Switzerland

SUMMARY: The town of Basle is the second in Switzerland. A growing chemical industry has given rise to complaints especially in respect of odours. Measurements have been taken of dust, SO_2 and H_2S, and it is concluded that, despite industrialization, the town still remains very clean.

Basle, with its 225,000 inhabitants, ranges immediately after Zurich, the largest town of Switzerland; it is beautifully situated on the Rhine on the north-west border of our country. Basle is a cultural centre of high reputation; at the same time the city is an important trade and banking centre where the headquarters of the main enterprises of the Swiss Chemical Industry are situated. A steadily growing number of chemical factories is spreading over the outer suburbs. In certain districts the complaints about air pollution have grown louder during the last years, especially in respect of odorous pollution, as smoke pollution can practically be disregarded.

In 1957 a special committee was set up by the Public Health Office in order to examine systematically the air of the Basle area and to elaborate some figures indicating the degree of pollution.

During the first stage of the investigation (1957–1959) the amount of dust and sulphorous compounds had to be measured. Dr. Bäumler of the cantonal research centre was in charge of these investigations. He applied the standard methods as used in Great Britain and Germany and worked with the instruments as used by the German Institute for Water-, Soil-, and Air Hygiene in Berlin, i.e., the rain-gauge of A. Lobner for dust (deposit matter) measurements and Liesegang's Bell-method for the SO_2 and H_2S measurements.[1, 2, 3] Direction and force of the wind were measured with the aid of a special wind recorder. The results have been compared with numerous figures worked out on the basis of similar methods, in Great Britain, Germany, Italy, U.S.A., etc.

The results can be summarized as follows:

Dust

The average proportion ranges between 200 and 600 g per 100 m² a month.

	g/100 m²/month
(a) In residential areas	150–350
(b) In suburban residential areas	200–400
(c) In residential areas near railway plants	300–450
(d) In industrial areas	500–600

The figures are substantially lower than the ones registered in town areas abroad. A. Heller fixes the upper limit of tolerable pollution at 3,000 g/100 m².

Sulphurous Compounds

(a) SO_2

Here again very low figures were registered. During the winter months the proportion amounts to 5–15 mg/S per bell, during the summer months only to 0–5 mg/S per bell.

So the proportion of sulphurous gases is practically none during the warmer season of the year and still very small during the winter period. No difference could be traced between residential and industrial areas. The situation is even contrary to what one may expect: liquid fuels—which are much used in residential areas—cause about the same pollution as the waste gases of industrial areas.

(b) H_2S

A very small proportion of sulphuretted hydrogen could be measured with the Liesegang-bell and lead acetate solution. In most cases the results were negative. Only in the immediate neighbourhood of industrial plants small quantities of H_2S were traced. The corresponding figures on the colour-chart of the German Institute for Soil-, Water-, and Air Hygiene range between 0 and 1.

Summary
Conclusions

It appears from the results so far obtained that despite the steadily growing industrialization the air of the town area still remains very clean in relation to deposit matter and sulphur. The proportion of sulphur dioxide is very small in comparison with the quantities measured abroad. But during the heating season, the air contains a rather higher proportion of sulphurous compounds all over the town, this being the result of the growing use of liquid fuels.

Sulphuretted hydrogen was only occasionally traceable in small quantities in the immediate neighbourhood of chemical plants.

Detailed results will soon be published.[4]

The measurements of dust and sulphur are to be continued and will be completed by detailed measurements of the air pollution due to motor vehicle exhausts.

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II. 15

CLEAN AIR IN CZECHOSLOVAKIA AND MEANS FOR IMPROVEMENT OF TODAY'S CONDITIONS

Ing. J. POLACEK, Technical Director, Research Institute of Air-Handling Equipment, Czechoslovakia

SUMMARY: The growing industrialization necessary to raise the standard of living is also causing an increase in air pollution. The types of emission, climatic conditions and effects of pollution are described. Extensive research is being undertaken and efficient methods of dealing with the pollution are being evolved, e.g. by converting industrial plants to natural gas.

The conditions in Czechoslovakia in respect of air pollution are very similar to those in Great Britain. The growth of our industry and standard of life is characterized by the rise of the index of kWh/head from 90 in 1945 to 1,340 in 1957, the rise to 1965 being planned for 2,670 kWh. The development of our industry is based on coal to 85 per cent. In steam power stations more and more low-grade coal is in use, because high-grade coal is preferred by the rapidly growing chemical industry in our country. As air pollution by the solid and gaseous discharge of our power plants, heavy and chemical industries has grown largely in industrial centres with a great density of population, our government began some years ago to pay much systematic attention to the abatement of the unfavourable effects of the growing industry on the health of our people, agriculture and forest-culture, so as to reduce the price for the increase in the standard of living to a minimum.

Already at the world power conference in Vienna and Belgrade our engineers have reported the realized and planned research work of our scientific institutions and the actions of our government leading to the abatement of air pollution by the improvement of existing equipment and widespread prevention of pollution by further planning of power plants and industry.

District hygiene and epidemic stations and laboratories are charged with systematically ascertaining air pollution and tracing the effects of pollution on the hygienic conditions of the population. They are tracing the air pollution by standard measuring methods in territories especially polluted by industrial discharge for several years. Principally, solid materials, such as fly ash, dust, soot, and gaseous discharges, especially sulphur oxides, are ascertained. In special cases nitrogen oxides, chlorine, carbon disulphide, monoxide and dioxide, ammonia, fluorine, hydrofluoric acid, sulphur acid, etc. are also measured.

Substantial abatement of dust deposit in recent years in some territories is effected by transfer of main power plants and industrial equipment to natural gas. In other regions the air pollution with the growing industrialization is still rising and according to the character of local industry solid particles or gaseous discharge predominates.

For objective research of unhealthy discharge effects on the hygienic conditions of the population convenient control groups of school children are used to eliminate the effects of working place and age.

So it was ascertained e.g. that the occurrence of conjunctivitis in endangered territories was 5–20 times greater than the standard; similarly in the case of indisposition of the upper respiratory tract. In another place a mild delay in the physical development of children, hypertrophy of tonsils and symptoms of neglected rickets were ascertained.

As to the losses caused by the industrial discharge to agriculture, vegetable-gardening, forest-culture and the look of the countryside, the research shows that even a small deposit of fly ash, characterized as allowable for people, is harmful to the flora. For vegetation in positions nearer to steam power stations, the fly ash is more harmful, while in distant positions the contents of sulphur oxides are worst. Among the wood-trees the spruce is most affected by fly ash while the pine, larch, birch, beech-tree and maple less.

Arsenic kills bees, which not only lowers production of honey, but also endangers the function of bees as highly important pollinators.

Of the various kinds of air pollution, first place is taken by industry followed by transport, traffic and dwellings. Of industry the first place is taken by big steam power plants, further metallurgical and chemical works, cement-works, coal mines, coke-ovens and coal sorting plants, power installations of goods and consumer industries.

The first place of air pollution in transport is occupied by railways, i.e. steam engines on tracks and industrial sidings, then road transport by motor vehicles. A remedy is being effected by introducing electric and diesel electric traction on main railway communications.

Dwellings take part in the air pollution by domestic stoves and power installations of community health and educational services. The removal of pollution is successfully realized by building district heating plants and combined heat and power plants and further by gasification and electrification of homes. In chemical industry we are working on removal of noxious discharge by electrolytic production of chlorine and in some places using it, as well as of discharge by the production of sulphur and nitric acids and waste gases from chemical processes of viscose production.

The air pollution by gaseous discharge from coal mines is caused in principal by gases arising by spontaneous ignition and combustion of coal and wastes of surface coal mines, further by wastes from quarries, dumps of coal mines and coal preparation plants. Important causes of dust are the processes and stages of dry-type coal preparation. For these reasons we proceed to the alteration of the technology by a new method based on wet-type preparation.

Regarding meteorology and climatology our state is situated in the middle of Europe and in respect to the climate it builds a transitory zone of western ocean and continental climates. In this sphere our country presents an especial closed territory, isolated from neighbouring countries by boundary chains of mountains, which owing to its orographic diversities excels by its varieties of meteorologic appearances. These climate conditions are less favourable for the natural dispersion of pollution in affected regions than in Great Britain.

As to the removal of noxious solid particles discharged from industrial plants, we are using for their separation aeromechanical collectors of high efficiency combined with electro-precipitators in the case of the collection of fine fly ash from coal dust firing. With power units of 50,000, 100,000, and 200,000 kWh efficiencies of 97–98 per cent are required. A special conference of our Scientific and Technical Association, Section of Sanitary and Air Handling Engineering, with participation from abroad has been held this September in order to solve the problem of developing suitable collecting equipment for the planned steam power stations of our country in our future five-year plans.

High efficiencies with small water consumption have been achieved by our newly developed wet-type collector; for our fibre filters special filtering media for temperatures of about 300°C are developed in our laboratories. The use of ultra-sound for precipitation of solid particles meets for the present with economic difficulties.

As to the removal of sulphur oxides from flue gases of steam power stations, existing methods worked out on experimental, or larger half-working scales, may not secure the economic solution of the problem in our conditions. Today we suppose that for our conditions owing to the necessary raw materials and market possibilities of gained products, we shall be obliged to use more than one of today's existing technologic processes for all our big steam power stations.

New wet and dry-type processes are being investigated experimentally in laboratories, but do not render in the meantime enough material for final economic evaluation.

THE FRENCH ASSOCIATION FOR THE PREVENTION OF AIR POLLUTION

Y. QUERET, Secretary-General of the Association

SUMMARY: The objectives and organization of the Association, which was formed in 1958, are described, and some of its principal activities are outlined. These include the measurement of air pollution and schemes for the setting up of smokeless towns, the first of which Boulogne-Billancourt, an important suburb of Paris, will be established this winter.

L'Association Francaise pour la Prevention de la Pollution Atmospherique (French Association for the Prevention of Atmospheric Pollution) was founded in July 1958. Under the authority of Professor Bugnard, Director of the National Institution of Hygiene, it groups all the prominent individuals of scientific circles who are particularly competent in matters of hygiene and air pollution, and members of the advisory committee of establishments "classified as dangerous and unhealthy", the Association of French Mayors, the Association of Chambers of Commerce, delegates of the National Council of French Employers and qualified representatives of the great industries interested in this question (railways, coal mines, gas, electricity, petroleum, chemicals, cements, etc.).

This Association has assumed the following main task:

(1) the promotion of the scientific and technical studies necessary for determining the causes of air pollution and its possible remedies.

(2) a campaign:
—to *inform* public opinion of the dangers of pollution due to domestic hearths and motor-car exhaust gases;
—to *educate* the public by articles in the press, lectures, films, exhibitions, congresses.

(3) efficient assistance to industrialists in seeking, jointly with them and under the most economic conditions, all means capable of reducing or suppressing air pollution caused by their plants.

(4) co-operation with the public authorities in drawing up simple and practical regulations to combat air pollution.

(5) contribution to the creation of "smokeless towns."

The organization of the Association comprises:

An *Editorial Committee* in charge of public relations —publication of the bulletin, exhibitions, various activities.

A *Scientific Commission* including the directors of all the specialized laboratories of the Paris district (Conservatoire des Artes et Métiers, Hygiene Laboratory of the Prefecture of the Seine, Municipal Laboratory, Toxicology Laboratory of the Faculty of Pharmacy, Laboratory of the Institute of Research in applied chemistry) in charge of unifying methods of analysis and research and standardizing pollution-detecting apparatus.

A *Technical Commission* in charge of implementing the conclusions of the scientific commission, particularly in initiating pilot "smokeless towns."

Finally, specific *Working Groups* are being formed for each industry, in particular for the cement industry.

The Association publishes a bulletin in which two issues have already appeared. It had a stand at the International Exhibition of Public Health which took place in Paris from 17th to 26th April, 1959, and at the Fifth International Exhibition of Industrial Chemistry (industrial heating section) which was held in Paris from 18th to 29th June, 1959.

During the International Health Exhibition, a one-day symposium, organized by the Association, was devoted to atmospheric pollution. It included three lectures and two demonstrations given on a platform in the centre of the Exhibition. Finally, on the last day, a round-table discussion, which was broadcast directly over the Europe No. 1 Chain, grouped all the specialists in the diseases and scourges which are rife among the populations (cancer, tuberculosis, alcoholism, etc. . . . and atmospheric pollution). The Secretary-General of the Association made a brief statement and answered several questions directly.

A series of lectures was given at the Conservatoire des Arts et Métiers of Paris, the Maison de la Chimie, in students' and engineers' clubs in Paris and the provinces, under the chairmanship and with the effective assistance of directors of the Association.

In addition, on 3rd and 4th December next, there will be two "informative symposiums" on atmospheric pollution, organized by the C.I.C.A.D. (Centre d'Information pour de Devéloppement du Conditionnement d'Air, de la Ventilation, du Filtrage de l'air et du Dépoussiérage),* the National Safety Institute, and the Association for the Prevention of Atmospheric Pollution. This symposium will be under the high patronage of the Ministers for Industry and Commerce, for Public Health and Population, and of Labour and Social Security.

Finally, under the auspices of the Prefecture of the Loire Department and in agreement with the Deputy-mayors of Rive-de-Gier and Roanne, Messrs. Hemain and Pillet, smoke and high acidity measuring apparatus have just been placed at various points of these towns to detect sources of pollution and their extent. After these measurements have been noted these towns will launch their campaign to promote air purification.

The same steps for detection of pollution are being taken at Boulogne-Billancourt, a very important Paris suburb, where, thanks to the activity of the Mayor, Councillor General of the Seine Department, M. Le Gallo, the first pilot smokeless city of the Seine Department will be established this winter.

Such are the main activities of the Association for Prevention of Atmospheric Pollution, which is now preparing a Congress to be held in Paris at the end of 1960 and has taken the necessary steps for its recognition by the Government as an establishment "for the public benefit."

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* (Information Centre for Developing Air Conditioning, Ventilation, Air Filtrage and Dust Removal.)

II. 17

PARLIAMENTARY INITIATIVE FOR THE PREVENTION OF AIR-POLLUTION IN GERMANY

Dr. O. SCHMIDT, Member of the Federal German Parliament, President of the Inter-Parliamentary Working Community, Bonn, Germany.

SUMMARY: The paper describes the steps which have led to the introduction of a Bill dealing with industrial air pollution. The Bill originated from the initiative of the Inter-Parliamentary Working Community, an organization of about 300 deputies of the Federation and the Laender. It has all-party support. Technical provisions have been specifically avoided in the drafting, as they soon become out-dated. It is hoped that the Bill will become law shortly after the Society's conference.

The Inter-Parliamentary Working Community, to which about 300 deputies from the parliaments of the Federation and the Laender, drawn from all political parties belong, took up this subject for the first time at their plenary meeting in Bonn on May 4, 1954, and in 1955 took steps to initiate legislation regarding observation of the atmosphere for radio-active fall out and its transportation. This was induced by the spread of the opinion among parliamentarians that the legal provisions for the prevention of air pollution were no longer adequate. It was decided that all pertinent material should be collected, and that experts should be asked for reports on the subject. On May 3, 1955, after a preliminary debate, it was agreed that a special meeting should be summoned to discuss this problem in more detail. This took place on July 5, 1955, when the matter was discussed from all angles; specialists and representatives from the Federal Union of German Industry, the competent Ministry and the Union of German Engineers (VDI) expressed their opinions, thus enabling a clear point of view to be gained as to the initiative which must be taken. The VDI was accordingly requested to convene a committee on questions of the prevention of air pollution, which met on November 7, 1955, and included specialists from all the fields concerned (e.g. hygienists, chemists, meteorologists, biologists, foresters and farmers, doctors, physicists, engineers, local government politicians, town and country planning specialists, etc.). This committee, which was later reorganized to an independent commission, submitted to the deputies of the parliaments a number of very carefully drawn up reports on the situation and on the technical possibilities of preserving the purity of the air.

Following a motion of the Christian Democratic Parliamentary Party, the Landtag of North Rhine-Westphalia, on December 13, 1955 requested the Land Government for a precise statement regarding the nature and extent of the proposed measures for preserving the purity of the air. On May 20, 1957 the Government submitted a highly-detailed interim report.

On July 4, 1956 the Social Democratic Party introduced a motion in the German Bundestag concerning air pollution (registered as Printed Matter No. 2598 of the 2nd Legislative Period), which was unanimously accepted and which led to a debate in the Plenary Meeting of January 11, 1957. The report for which request was made was submitted to Parliament on July 31, 1957 by the Federal Ministry of Labour, in agreement with the other departments concerned (Printed Matter No. 3757). The problem of preserving the purity of the air was also treated in a number of other Land Parliaments, from the most varied points of view, in connection with which the offensive smells emanating from fish factories played a part in the case of coastal towns.

From all these data and discussions it became increasingly evident that rapid parliamentary initiative was necessary, since a Government bill would have taken a longer time.

By the time the Plenary Meeting of the Inter-Parliamentary Working Community took place on December 4, 1957, the preliminary work had progressed so far that instructions to prepare the draft of an Initiative Bill could be given. In another special meeting on February 11, 1958 the final draft was drawn up and members of all political parties in the Federal German Parliament introduced the draft bill in the form of a motion on March 22, 1958 (Bundestag Printed Matter No. 301).

An important feature of the draft Initiative Bill was that all technical provisions were omitted from the proposed legal measures, since only in this way can it be avoided that the legislator, in view of the developments of engineering, leading to new sources of pollution and new measures of protection, is constantly faced with the necessity of introducing amendments to the existing law. The legislator must also take into account progress in this field by ensuring that his law constitutes a flexible framework, which does indeed lay down the content, purpose and scope of the provisions, but which can be applied by the Government in accordance with the latest advancements in engineering, and which can, if necessary, be quickly supplemented. It was accordingly decided that the list of plants subject to obligatory control should from the beginning be excluded from the existing legal regulations, and should be inserted in the requisite decree, so that they can always be quickly supplemented. Another innovation is the demand for a control with liability for costs by the plant, and in particular the possibility of subsequent levies on already existing enterprises. In order that these ideas should not only be founded upon public law, but also upon civil law, a motion was also introduced for an amendment of the Civil Code.

The Federal German Parliament handed over the draft to a number of its committees, which, after hearing the opinions of representatives of the Government and of specialists on the subject, went into the matter in great detail. After certain proposals for amendment from the movers and other necessary alterations have been taken into account, the Steering Committee will submit a report to the Plenary Assembly of Parliament. The movers hope that by the time the International Clean Air Conference takes place the bill will have passed its third reading in Parliament and will shortly after become effective. It will then be the duty of the Executive to see that the regulations are applied appropriately. The details of how this is to be done are contained in the report submitted by the Federal Ministry of Labour.

In conclusion it should be pointed out that the German parliamentarians concerned are well aware that their draft Initiative Bill now before Parliament only introduces better regulations for part of the operational field, i.e. industrial plants. They believe, however, that this step will bring them considerably nearer to the goal which they have set themselves. Preliminary work concerned with undertaking measures against the pollution of the air by motor vehicles etc., was therefore, at once, begun.

PROGRESS AND THE FUTURE IN AIR POLLUTION CONTROL IN ALLEGHENY COUNTY, U.S.A.

LEE SCHREIBEIS, Jr., Acting Chief, Bureau of Air Pollution Control, Allegheny County Health Department, U.S.A.

SUMMARY: A brief summary of the history of pollution abatement in Pittsburgh is followed by a description of measurement methods used, with examples of figures showing the decline in pollution levels. This is followed by a description of sources of pollution. Particular attention is drawn to the high fuel consumption in the area and the problems of domestic waste disposal.

Introduction

The progress in air pollution control in Allegheny County has been exemplary since the end of World War II. Prior to that time and for more than 100 years the city of Pittsburgh was notorious as a dirty, smoky city. Efforts to improve the cleanliness of the city's air date back to the late 19th century, and beginning in 1912 several ordinances were enacted and enforced. The annual reports of the Smoke Control Bureau during the years 1912/1930 indicate some progress and regression in the difficult programme of eliminating or reducing smoke levels. The main sources contributing to this undesirable situation were thought to be limited to commercial, industrial, railroad and river boat operations. The multitudinous but smaller sources of home and apartment house heating plants were recognized but were not considered important contributors. Possibly the number of such heating plants and the means of obtaining improved operation in them were considered an insurmountable obstacle. During these early years of control effort, while improvements were realized and reported, the growth of the community added new sources of all kinds—new homes and increased commercial and industrial activities necessary to an expanding population. Thus, the net effect realized in the late 1930's and early 1940's was an extremely unsatisfactory smoke pollution problem. On the basis of experiences reported by St. Louis, Missouri, the government of Pittsburgh enacted a new ordinance in 1941, the enforcement of which was delayed until the termination of World War II.

Several factors which contributed to the ultimate success of smoke reduction in Pittsburgh were developed during the war period. The construction of the famous Big Inch pipe line, the development of underground gas storage reservoirs, the advent of the diesel engine on a grand scale, and the training and planning of the Smoke Control Bureau under Mr. S. B. Ely, all contributed, together with the desires of the majority of people, to the success of the endeavour. The degree of improvement in atmospheric cleanliness can be measured both subjectively and objectively. Subjectively, the great majority of residents, as well as returning visitors to this area, express satisfaction and approval of the progress in improving prevailing atmospheric conditions. Quite naturally, there are certain areas in which the pollution levels are not considered acceptable, and it is the responsibility of our agency to work with the various contributors of pollution to reduce these sources. There are a few records available that permit us to evaluate objectively the changes in pollution levels over the years. Several new sampling procedures have only recently become available which provide additional knowledge of the magnitude of specific pollutants. We are operating some new sampling equipment and plan to add other samplers. There are still many gaps in our knowledge of the significance of air pollution levels and the related health and other adverse effects. Extensive research efforts are being exerted to fill the wide gaps in our understanding and we believe one of our most important functions is to engage in such investigative work when it applies to the needs in Allegheny County.

Some of the available records which cover a sufficient time period to recognize trends in air pollution levels include: (1) visibility observations; (2) dustfall measurements; and (3) sulphur dioxide concentrations. The following brief summaries of these records will serve to show in objective terms the progress thus far achieved. It should be noted that the improvements were made during a period of population increase and industrial and related growth.

Visibility Records

Reduced visibility resulting from air pollutants is an experience we have all shared. Tremendous numbers of small solid particles and condensed vapours form this smog or haze, and visibility is but one measure of such air pollution. Its effects are realized in the soiling of various kinds of property and the nuisance of personal irritation. In 1946, records compiled by the United States Weather Bureau in downtown Pittsburgh show that visibility was significantly reduced by air pollution during an average of almost one of every four daylight hours in the year (i.e. there were 1,002 hours of reduced visibility and there are approximately 4,400 daylight hours in one year). Last year, 1958, the number of hours of reduced visibility was 64; thus, a reduction of about 94 per cent by this measurement has been recorded. This represents a tremendous improvement and is a credit to all who have contributed in the community effort. The year by year results are plotted in Fig. 1. Three lines are shown: the lowest line represents the hours of heavy smoke, which means that visibility was reduced to less than three-eighths of one mile; the middle line represents the hours of moderate smoke wherein visibility is less than three-quarters of one mile; and the top line represents the summation of hours of heavy and moderate smoke for each year. These observations have served and will continue to serve the community in evaluating trends in the visibility aspect of air pollution. Owing to the many recent developments in air sampling and monitoring, the Bureau now has the opportunity to evaluate with great sensitivity various qualitative factors of air pollution. Certain of these, comparable to the visibility record, have been in operation about two years.

Dustfall Records

Probably the oldest sampling method, and the simplest, is the dust deposit gauge. It was used in Britain prior to this century and in Pittsburgh by

Smoke Reduction based on U.S. Weather Bureau Visibility Records, Pittsburgh, Pa, 1946 - 1958

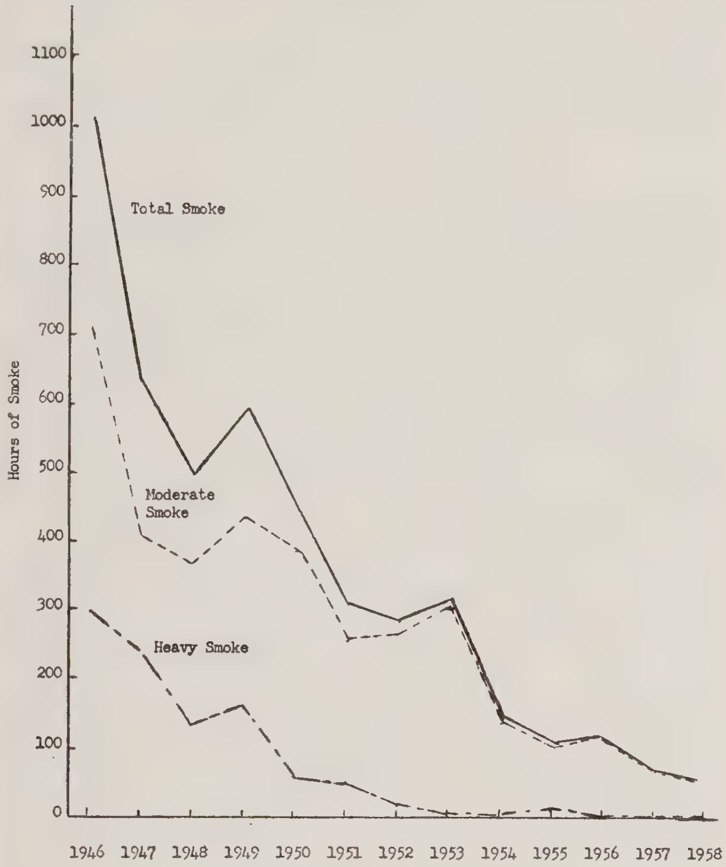

Figure 1

Dr. H. B. Mellor at Mellon Institute during the 1930's. The collecting device is a glass or stainless steel container which is placed on a stand 3 ft. above the roof of a suitable building and exposed for a one-month period. Dust settling out of the atmosphere is collected and later weighed. Various tests can be made of the sample, but for comparison purposes the weight of insoluble solids only are reported herewith. Several disadvantages to a truly quantitative result exist in the method, but it does reflect differences in dustfall rates in the community and is a useful indicator of trends. In six districts in Pittsburgh, sampling locations have remained the same since 1939. A brief summary of yearly averages of dustfall rates for these districts (Downtown, Lawrenceville, Squirrel Hill, East End, Oakland, and West End) is given in Table I.

Table I

Insoluble Dustfall Settling Rates for Six Locations in Pittsburgh

Concentrations expressed in tons per square mile per month

Year	*Range of Lowest to Highest Rate*	*Averages of Six Locations*
1939–40	32·6–97·0	58·6
1948	33·8–79·0	51·5
1958	22·0–39·0	30·5

It is noteworthy that the sampling location with the highest dustfall rate in 1939–40 has always had higher rates than the other five stations, but the reduction (97 to 39 tons per square mile per month) has been extremely large. The per cent reduction has been about the same at each of the other five stations. The average reduction in dustfall at the six locations (from 58·6–30·5) is about 50 per cent during the 18-year period. This tends to indicate that the fine particles (especially smoke) which contribute most to reduced visibility have been better controlled than the coarse particles which affect the dustfall nuisance.

Gaseous Pollution

The most apparent pollution in Allegheny County consists of various particulate compounds, such as smoke, dust and fume from numerous sources and fly ash. However, gaseous pollutants, such as sulphur dioxide, hydrogen sulphide and various odoriferous vapours, have caused nuisance and property damage in several localities. The Bureau has been provided with automatic sampling equipment and other facilities to evaluate the magnitude of sulphur dioxide and hydrogen sulphide pollution in certain locales. The results of sulphur dioxide concentrations at three locations in the County (McKeesport, Lawrenceville and Hazelwood) indicated average concentrations, during 1,600 hours of sampling, of 0·042, 0·048 and 0·056 parts per million parts of air (ppm). These values are all well below values associated with odour or health effects by sulphur dioxide, and cannot be evaluated on the basis of corrosion damage since benchmarks for these effects are unknown. The three locations represented areas where sulphur dioxide concentrations would be expected to be higher than normal. Peak concentrations of approximately 0·6 ppm were measured on several occasions at each station. It is interesting to note that the results of a sulphur dioxide survey, at various stations within the Pittsburgh metropolis, in 1936–1937 gave an average concentration of 0·078 ppm for approximately 300 hours of sampling. The maximum concentration measured was 0·9 ppm. The results of these two surveys are not exactly comparable owing to the sampling station location differences.

Several studies of hydrogen sulphide pollution have been made and others are in progress. The principal effects of this gas are unpleasant odour, paint damage, and potential corrosion. Public complaints of odour are common about industrial sources of this gas and methods should be developed to relieve chronically objectionable conditions. Paint damage has occurred with sufficient frequency from some industrial sources to further support the cause and need for better control of hydrogen sulphide pollution.

The preceding records are the only available guides to the magnitudes and trends in air pollution levels in Pittsburgh and Allegheny County during the past ten or more years. It seems obvious that the health and other effects of air pollution cannot be evaluated on such information. We need to know a great deal more about the concentrations of specific pollutants, such as the numerous hydrocarbon compounds, the oxides of nitrogen, ozone, aldehydes, etc. This Department is co-operating with the United States Public Health Service in obtaining additional sampling equipment and procedures for use in this area. We are planning to expand the community air pollution sampling programme to various selected areas in the county. The plans for the various sampling programmes will be submitted to the Advisory Committee for review in the near future.

Air Pollution Sources

Let us now consider some of the fundamental sources of air pollution in Allegheny County, and the progress made in reducing these sources. In such an examination there will be areas of great improvement and also of less improvement. In each instance, however, we shall see guides to direct the future programme of the Bureau in obtaining the highest possible degree of cleaner air.

Fuel Consumption

Energy consumption is the prime indicator of the magnitude of potential air pollution in an area. The type of energy used, whether coal, oil, gas or water power, is a second factor. Some statistics will show the trends in type and amount of energy consumption for the Nation and Allegheny County. In Table II total energy consumption values are given.[1] The values for Allegheny County are estimates made on the basis of fuel consumption throughout the State.

Table II

Energy Consumption of all types expressed in 10^{15} BTU

	1946	1954	*Per Cent Increase*
United States ...	30·4	37·3	22·7
Allegheny County ...	0·46	0·52	13·0
% Allegheny County of United States ...	1·5	1·4	—

The energy consumption *per capita* in 1946 was approximately 8·3 tons of coal (1 ton equals 26 × 10^6 BTU) in the United States and about 13·1 tons of coal in Allegheny County. In 1954 these values were increased to 9·0 and 13·5 tons *per capita* for the United States and Allegheny County respectively. The much higher energy consumption *per capita* in Allegheny County is the fundamental cause of our air pollution problem. Compare these values with an estimated world consumption (1953—3 × 10^9 estimated population; 42·1 × 10^{15} BTU), excluding the United States, of about 0·5 tons *per capita*. The type of energy used is given in Table III.[1, 4]

Table III

Type of Energy Consumption in the United States and Pennsylvania during 1946 and 1954

	1946		1954	
	Penna.	*U.S.*	*Penna.*	*U.S.*
Coal ...	68·0	47·9	52·2	29·3
Bitu. ...	(48·5)	—	(41·6)	—
Anthra.	(19·5)	—	(10·6)	—
Oil ...	23·4	31·9	32·9	41·8
Gas ...	7·2	16·0	14·1	25·0
Water Pwr.	1·4	4·2	0·8	3·9

Two relationships stand out in Table III. Pennsylvania, and more particularly Allegheny County, uses a much higher proportion of coal energy and less of oil, gas and water energy than the rest of the nation. The trend in Pennsylvania and Allegheny County, however, is towards higher proportions of oil and gas energy. The significance of this trend has both favourable and unfavourable aspects with respect to air pollution, which will be elaborated on in the next section.

The increase in fuel consumption and processing of raw materials in Allegheny County can undo much of the progress thus far made in reducing pollution levels. The reduction in dustfall at six stations was reported to be about 50 per cent. If our sources should double in the next two decades and the present level of collection efficiency of sources were maintained, we could conceivably return to the dustfall levels of 1939–40, which were so objectionable. Doubling of energy consumption is a prediction of most authorities[1] during the period 1954–1975. What the doubling of such fuel consumption and raw material processing will add to organic gaseous and vaporous pollution is a question to be given serious consideration. We must plan our programme to prevent increases in air pollution resulting from growth in population and related expansion of various activities. This becomes progressively more difficult as expansion proceeds. Therefore, we must require the best control features for all new installations and continue to seek improvement of existing sources.

The most important contribution to the lessening of smoke and other particulate air pollution in this area has been, in my opinion, the conversion of thousands of homes from coal to gas fired heating equipment. Comparisons of the particulate pollution from each type of furnace, if available, would reveal tremendous differences. In addition, the low height of discharge and the proximity of residential sources adds to the adverse effects of any pollution which is emitted. There is no doubt that home heating with gas is the most advantageous use of this fuel from the viewpoint of reduced air pollution. It is fortunate that a cost analysis of domestic fuels in Allegheny County reveals gas to be economically competitive.

New homes throughout the county have been equipped, in the majority of cases, with gas fired heating equipment. We are indeed fortunate for this development. I hesitate to contemplate the magnitude of the air pollution problem if natural gas fuels were not available in the quantities now used, especially for home heating.

A contribution of almost equal importance to reduced particulate pollution has been the conversion by the railroad and river transportation industries. Diesel engines are superior in other ways in addition to an estimated hundredfold decrease in solids discharge to the atmosphere. Various considerations indicate that diesel engines will continue to be the choice of the transportation industry, and control programmes will encourage this favourable development. Diesel exhaust gases from local bus and truck traffic are receiving attention in New York and Los Angeles and several complaints have been raised in our community. It will be necessary to consider this problem in the near future, since in many cases improved conditions can be obtained by proper engine maintenance.

Several other changes have resulted in improvement of our air pollution levels. Each will serve as a guide in developing a programme for the future. The participation of our commercial establishments in the " Golden Triangle " and the Civic Centre in Oakland in central heating plants has been extremely beneficial. In 1958 two central heating plants in Pittsburgh reported the collection of 95·6 per cent of the total ash in the coal, i.e. total ash was 11,740 tons and ash collected in ash pit and collectors was 11,224 tons per year.

Improved fuel-burning equipment and operation in commercial and industrial plants using coal have helped measurably. An awareness of the problem and willingness to co-operate in providing the necessities for improved combustion efficiency are two of the keystones of continuing success. A large part of the Bureau's effort will be directed to obtaining the equipment and operation that will produce the least air pollution with due consideration for other factors.

Open Burning

Many sources of smoke and odour pollution arising from scrap and junk yard open burning have been stopped. These salvage operations were a severe nuisance in many localities and contributed significantly to the overall pollution levels. Our view in this regard is to maintain the ban on such commercial burning and at the same time to encourage the development and installation of suitable incinerators or other disposal techniques. Commercially available and acceptable junk yard incinerators for the burning of automobile bodies have been operated in New York and other cities. An incinerator for reconditioning steel drums has been installed in Pittsburgh recently, which eliminated an extremely objectionable nuisance. Numerous other industrial type incinerators have been installed and work well in minimizing air pollution. We strongly recommend the continuation of the programme to encourage the design and construction of industrial incinerators capable of performing in accord with the highest reasonable standards.

Industrial Sources

The many contributions to improved atmospheric cleanliness of industrial operations in the county are recognized, but the observable emissions indicate that further control measures are needed in certain localities. A large amount of money has been invested in research activities by industry to find out just how to control certain of the difficult sources of pollution. While many instances can be cited, time will permit mentioning one. The problem of open hearth fume and dust discharges include high temperature, fine particle sizes of the material, rather large volumes of exhaust gases, difficult material handling and final disposal problems. Investigation and study by authorities in the gas cleaning and steel industries have indicated that electrostatic precipitation is the most practical solution to-date. However, the cost of such installation is very high. Slag wool filtration, wet scrubbers, and glass bag filters are being studied in order to find a more economical solution. Thus far, the prognosis for alternative and less expensive cleaning methods is only fair. The following tabulation indicates the progress in open hearth fume control in the Nation and Allegheny County, based on reported installations by steel industries:

Table IV

Open Hearth Fume Collecting Installations

	Number of Open Hearths	*Number Equipped with Collectors*	*Per Cent Equipped with Collectors*
United States ...	920	44	4·8
Allegheny County	102	12	11·8

Other studies on smoke and dust emissions and their control in electric furnaces, Bessemer converter, cupolas, coke ovens, blast furnaces, boiler furnaces, and other equipment are in progress or have led to practical solutions. The next step is the application of feasible solutions to those sources of air pollution contributing most significantly to the problem in Allegheny County. Studies are needed to evaluate the direct role and per cent contribution of the various kinds of equipment. We are planning to make such investigations in order to be better able to advise and promote this important phase of the industrial air pollution control programme.

Domestic Refuse Disposal

Other air pollution sources pose present problems for which solutions need to be developed. I refer particularly to domestic and commercial refuse disposal. The present ban on open burning in Allegheny County presents us with a dilemma since adequate collection services are not provided in most of the communities. Incidentally, there never has been nor should there be application of the open burning ban to backyard and picnic ground cooking and barbecuing. The Ordinance, however, probably should be rephrased in this respect. The tremendous expansion of our population in the suburbs and the concurrent increases in the amount of disposable paper and food wastes *per capita* have not been foreseen in the provision of needed refuse collection and disposal services. We need to re-examine methods for solving the open burning of rubbish, which is so common a practice in Allegheny County outside the city. It is a problem, as evidenced by our complaint file and by an investigation of backyard rubbish burning by the Battelle Memorial Institute. They report a range of 32–407 lb (1·6–20·4 per cent) of organic materials (phenols, aldehydes, methanol and hydrocarbons) from each ton of typical domestic rubbish. These and other organics produce the obnoxious odours so frequently complained about. In addition, at least 20–40 lb of particulate matter from each ton are made air-borne. Other air pollution control agencies are approving the newer domestic incinerators meeting the A.S.A.[2] Standards. This Bureau is planning to review the entire question of domestic incinerators with a view to encouraging the development and installation of adequate units. It is believed that the long-range solution lies in this direction for reasons of convenience and cost.

Our programme for the examination and approval of commercial and apartment house incinerators is believed to be obtaining satisfactory results. The design of such units meets the recommendations of the best available research findings. However, there are many older units, installed without benefit of present knowledge, which have given rise to complaints. We are endeavouring to improve the facilities and operation in such cases, but it is a recurring and difficult control problem.

Auto Exhaust

A few words are needed in appraising the status of automobile exhausts. In Los Angeles auto exhaust gases are cited as the primary source of pollution. Development of an exhaust gas device to destroy the deleterious substances has been under investigation for several years and seems to be very near at hand. Reports indicate that such exhaust control devices will be required on automobiles in Los Angeles and other cities in California in the near future. In

Allegheny County we believe such a problem should be given serious consideration. As traffic increases, we may be able to benefit from the pioneering experiences in the West. At the very least we must recognize that the magnitude of pollution from this source is great, and the health implications of the organic vapours discharged from auto exhausts are potentially important.

Other Pollution

Other air pollutants which are receiving considerable attention throughout the nation include radioactive fall-out and air-borne pollens. At the present time the Atomic Energy Commission is sponsoring a programme of evaluation in various phases of the fall-out problem. Owing to the far-reaching implications of the radiation health hazards and the differing view as to the significance of the existing problem, a recent report has recommended the expansion of responsibility and research in this field by the United States Public Health Services.

Studies in other cities on contamination of food, milk and air with radioactive materials settling out of the atmosphere have given rise to differing evaluations of the significance of this problem. Very little is reported on results of tests by the A.E.C. in this area. Our Bureau is co-operating with the United States Public Health Service in a nation-wide sampling programme, part of which includes an examination of certain radioactive emissions. It is our view that the problem of air pollution with radioactive particulates should be considered by this Bureau, and a programme planned in preparation for the expanded use of such materials in our community. There is also need for developing, in co-operation with the Allegheny County Civil Defence Organization, a plan for service in the event of a nuclear explosion disaster which will result in wind and air-borne pollution transfer over considerable areas.

Ragweed and other pollens can be a source of extreme irritation as some of you may know from personal experience. A great deal of interest in the control of this nuisance has been reported by various agencies in the country. On the basis of our study of the concentrations of air-borne pollen in Allegheny County in 1958, this area is subject to high pollen counts. In Oregon, New York, New Jersey, Michigan, and other States a weed control programme has been inaugurated and the progress reported is encouraging. Detroit has reported in great detail on the success of their effort.[3] Pittsburgh has accomplished some results with a limited weed eradication programme. This Bureau is planning to conduct a seasonal pollen count study and to investigate the feasibility of an eradication programme.

Conclusion

Much has been accomplished in our county to provide a cleaner atmosphere. However, one does not have to travel very far in any direction of this county to find people who are dissatisfied with the progress in their localities. This Bureau receives about 800 written and telephoned complaints each year. We must also consider the effects of the expansion of population and the industry and services required to support them in the coming decades. The President's Materials Policy Commission and others predict our energy consumption by 1975 will be twice the value used in 1954.[4] If Allegheny County shares proportionally in this growth ,we must further reduce our existing sources of air pollution as well as strengthening the requirements for all new installation. It is quite possible that, unless we do continue to show the magnitude of progress made in the past, some of our descendants will have to begin again the groundwork and the programme of the past 13 years to remove the title of smoky or smoggy from our community.

References

[1] The Mineral Industries Experiment Station, College of Mineral Industries, the Pennsylvania State University, Progress Report No. 1 (April–June, 1957) and Progress Report No. 2 (July–December, 1957).

[2] American Standards Association, Inc., A.S.A., Z21.6—1957.

[3] John H. Ruskin, " Hay Fever: An Evolving Problem for Sanitarians ", Publication of Detroit Department of Health.

[4] A Report to the President by the President's Materials Policy Commission ", June, 1952, Resources for Freedom, Volume 1, Foundations for Growth and Security.

II. 19

AIR POLLUTION PROBLEMS IN CZECHOSLOVAKIA

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SUMMARY: Air pollution has become a problem in Czechoslovakia in recent years. The main sources are coal burning, smelting and chemical industries. The two worst affected areas are Ostrava and Usti n. L. Measurements are being made and laws are being promulgated setting out maximum emission from new plants. Work is going ahead on all aspects of prevention, including potential dangers of atomic power stations and motor vehicles.

Introduction

The growth of industrial production and the increasing demand for energy on the one hand, and the great density of population and the higher outputs in agriculture on the other hand, make the problem of air pollution in Czechoslovakia one of the important problems of economy and hygiene.

Czechoslovakia belongs to the densely inhabited states (105 inhab. per sq. km.) and has a dense population especially in her most industrial and smoky areas, e.g. in the region of Usti n. L. (163 inhab. per sq. km.) and Ostrava (186 inhab. per sq. km.).[1]

A big growth of industrial production as well as consumption of energy in recent years are the causes of the concentration of industrial aerosols, harmful gases, and vapours, which bring about great economic damage in agriculture and forestry, public health, raw material bases, etc.

The quality and quantity of air pollution in Czechoslovakia are determined principally by the kinds of fuels burned in power plants, thermal power plants, by the railways, and for domestic heating, and by smelting and chemical industries. The main sources of energy now in Czechoslovakia are brown coal and hard coal, the power plants and thermal power plants consuming chiefly coal of inferior quality (coal-dust) with a high content of sulphur. Also the railways, only partially electrified at present, use these inferior fuels extensively. The pollutants caused by chemical and smelting industries are only secondary. Pollution by the exhausts of motor vehicles is not of the same importance in Czechoslovakia as in other countries; it must be taken into account, however, that in the near future, about 3–5 years, this problem will become serious.

The present state of air pollution in Czechoslovakia

The systematic qualitative and quantitative measuring of pollutants in Czechoslovakia started only five years ago. During this period values of the dust fall-out have been obtained from most industrial regions and major cities, and in many of them concentrations of SO_2, Cl_2 and $NO+NO_2$ were also studied. Though the whole territory of Czechoslovakia was not surveyed and the methods used not quite unified, the results (Table 1) show, even now, that air pollution by ash and soot has been highly excessive. Concentration of SO_2 especially in the surroundings of big thermal power plants goes beyond permissible limits (Table II). The highest air pollution in Czechoslovakia is in the great industrial and coal regions of Ostrava and Usti n. L. In the environment of Usti n. L.[2] is the largest brown coal basin in Czechoslovakia extending between Chomutov and Usti n. L. over an area of 800 sq. km., with many big thermal plants. In some of the surroundings of these power plants the fall-out of industrial dust reaches 3,000–4,000 tons per sq. km. annually. Also the average fall-out of dust in the big cities of this region is high (Table I). The whole region has been afforested to a high degree, and the industrial pollutants and SO_2, SO_3, and Cl_2 damage forest culture especially, in the first place, the spruce copse-wood. The exhalations SO_2 and SO_3 are retained by the hillsides of the Krusne Hory Mountains and damage the spruce copse-wood in the higher altitudes (above 600–800 metres).

Still worse is the region of Ostrava, having a greater area attacked by pollutants. The main source of pollutants are again the thermal electric works and smelting industry. Together with the industrial expansion appeared the problem of an increasing air pollution. The average fall-out of industrial dust in this region was 557 tons/sq. km in the year 1954 and rose to 1,018 tons/sq km. in 1958. The average fall-out dust of the whole region of Ostrava–Karvina amounted to 520 tons per sq. km. in 1954 and 688 tons/sq. km. in 1958. When in 1954 only 26·3 per cent of the whole area of Ostrava–Karvina was polluted more than 400 tons/sq. km, in the year 1958 already 73·8 per cent of the whole area was polluted by the fall-out dust annually. The centre of this region, the city of Ostrava, owing to its average of fall-out dust (1,018 tons/sq. km. annually), is among the smokiest cities in Czechoslovakia (Table I). The industrial establishments penetrate into the densely inhabited and commercial quarters, the residential quarters thus showing an average over 2,000 tons per sq. km., and the very centre of the city even 3,000–6,000 tons per sq. km. annually. Also many other of the smaller industrial regions and industrial cities register a high fall-out of dust (Table I), with an influence, however, only on smaller areas in the vicinity of factories. To these regions belong industrial cities and industrial establishments of Prague, Brno, Bratislava, Kladno, Beroun, Kraluv Dvur Plzen, Pribram, Zilina, Prerov, Cheb, Sokolovo, Porici, Chvaletice and Ejpovice.

The control of the clean air, the laws and technical arrangements

Periodical quality measurements of fall-out dust, and concentration measurements of SO_2 and other harmful gases, have been carried out by the hygiene service laboratories in every town district, by laboratories of several research institutes, and by the Academy of Sciences. The fall-out of dust was determined by the method of a passive sedimentation. The sediment was captured in glass funnels partly filled with distilled water; concentration of the fine aerosol /0·1–5μ/ was determined by the method of membrane filters, and that of SO_2 polarographically.[4] [5] [6]

The basic law for the protection of the atmosphere in Czechoslovakia is the Law of Hygienic and Anti-epidemic Care, dated 1952 (zakon c. 4.Sb z 28.III. 1952). Under it rests the hygienic and anti-epidemic care—besides other provisions—in respect of precautions as to the admissible impurity of air from the

Table I

Average fall-out of industrial dust and concentration of SO_2 in industrial cities in the year 1958

Town	*Fall-out* t/km^2 *year*	*Aerosol* mg/m^3	SO_2 mg/m^3
1. Tabor	75	—	—
2. Vrchlabi	98	—	—
3. Jihlava	128	—	—
4. Nova Paka	181	—	—
5. Strakonice	190	—	—
6. Brno	195	—	—
7. Pribram	200	—	0·25
8. Ceske Budejovice	216	0·33	0·009
9. Karlovy Vary	302	—	—
10. Praha	331	0·66	0·065
11. Kladno	400	—	—
12. Plzen	418	—	—
13. Beroun	450	—	—
14. Sokolovo	702	—	—
15. Porici	750	—	0·16
16. Ostrava	1,018	—	—
17. Kraluv Dvur	1,300	—	—
18. Stara Role	1,487	—	—
19. Usti n. L.	1,550	—	—
20. Ervenice	1,969	—	—
21. Komorany	3,600	—	—

Table II

The permissible concentrations of some hazards in the free air

(*According to the preliminary hygienic instructions in ČSR, Acta hygienica* 8, 13 (1959)).

(The fall-out of industrial dust ... 150 t/km^2 year)

Hazards	*The average concentration during 24 hours;* mg/m^3	*The maximum of immediate concentr.;* mg/m^3
Nontoxic dust ($<10\% SiO_2$)	0·15	0·50
Soot	0·05	0·15
H_2SO_4	0·10	0·30
Tar	0·10	0·30
SO_2	0·15	0·50
CO	2·00	6·00
($NO+NO_2$) as NO_2	0·13	0·40
H_2S	0·005	0·015
Cl_2	0·02	0·06
CS_2	0·15	0·50
HCl	0·02	0·06
Pb	0·0007	—
Hg	0·0003	—
Phenollum	0·10	0·30
F_2	0·01	0·03
As (besides AsH_3)	0·003	—
NH_3	0·1	0·3
MnO_2	0·01	0·03

standpoint of health (S_2). In a decree issued by the Ministry of Health in the year 1954 (c. 24. Sb. ze dne 7. V. 1954) were furthermore specified limits concerning the cleanliness of air with corresponding sanitary regulations. For the present any officially stated maximum concentrations of dust, noxious gases, and vapours, do not exist in Czechoslovakia. Table II shows the approximate values, however, that are being used. Only new factories and power plants have to disperse the products of combustion in free air under the condition that the emissions will not contain more than 100 mg/cub. m. (the particles should be smaller than 100μ) and that the sanitary zones between factories and dwelling-places will be maintained.

Damage due to air pollutants has not yet been completely estimated for the whole territory of Czechoslovakia. It may, however, amount to several millions of Cz. crowns annually. For example, in the already mentioned country of Usti n. L. the damage is estimated to be 32 mill. Cz. crowns (10·5 mill. Kcs on copsewood, 9·4 mill. Kcs in agriculture, 0·4 mill. Kcs in sanitary matters, 1·7 mill. Kcs in water economy, vegetation and works of art, 2·0 mill. Kcs on industrial equipment and buildings, 3·5 mill. Kcs on raw materials and 4·5 mill. Kcs were indirect losses to inhabitants). In order to prevent further deterioration of atmosphere, to gradually clean the air and to restore natural conditions in Czechoslovakia, the government resolution was published to protect smoky regions of economic importance, in the first place the regions of Ostrava and Usti n. L. Several sections of the Czechoslovak Academy of Sciences, air technical institutes and institutes of hygiene, and also some other research institutes started work on problems of air cleaning and recovering of nature, because air pollution of any other regions would seriously endanger sylviculture and agriculture (spruce and pine woods, hops, etc.) of Czechoslovakia.

The aims of future action against air pollution

The principal task of the Czechoslovak industrial plants and of the sanitary and air technicians is to introduce to all great thermal power plants and electric works methods for the perfect technical cleaning of flue gases from ash and grit. Complete electrification of railway traffic is also necessary. This task may be solved by our techniques. More difficult will be the cleaning of flue gases from SO_2 and some other gases and vapours. From an economic standpoint this problem has not yet been solved anywhere in the world. Competent institutes—and also the Academy of Sciences—are therefore about to carry out research on capturing and recovering SO_2 in flue gases Other tasks are the basic research on aerosols and technical research in the sphere of neutralizing the very fine aerosols, which are to be reckoned with in the near future.

In future Czechoslovak energy production must be orientated to the exploitation of atomic energy (building up atomic electric plants) and burning of oil fuel distillation residue. Besides, a great development of motor-car traffic is expected. All these are the main sources of fine aerosols with dangerous effects on health and nature, the neutralization of which presents considerable difficulties.

The density of population in some countries will prohibit the emission of greater concentrations and thus the development of atomic and oil fuel electric plants is dependent on a well developed technique of capturing and neutralizing these fine aerosols.

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AIR POLLUTION LEGISLATION AND ADMINISTRATION IN THE UNITED STATES

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SUMMARY: Since World War II increased interest in air pollution control has led to legislation at Federal State and local levels. The Federal Air Pollution Research and Technical Assistance Act was passed in 1955. The methods by which State, Regional and local control is carried out, are described. Independent air pollution control agencies are supportable only by large population groups. A minimum budget of 5 cents per capita is needed.

Air pollution control is based on the premise that the atmosphere may not be used as a receptor of wastes to the extent that there will be demonstrable adverse effects on the health, comfort or property of others.

Early air pollution control legislation in the United States attempted to meet the most obvious causes of pollution—smoke, odours and partially-burned solids. As the use of liquid and gaseous fuels increased, and as industrial and technical processes grew in number and complexity, so did air pollutants. While smoke and soot are still problems in many areas, increasing attention is being paid to the presence of other, less obvious contaminants, including radioactive wastes.

Since the end of World War II, the increasing interest in conservation of the air resource of the United States has been reflected to some extent by the adoption of pertinent Federal, State and local legislation. Within the last decade more than 20 States have modified existing legislation or adopted new legislation on air pollution. A comparable rise in legislative activity has occurred at the community level[1].

In the Federal Air Pollution Research and Technical Assistance Act of 1955[2] recognition is given to the dangers to the public health and welfare, the damage to agriculture and to property, and the hazards to ground and air travel created by air pollution. The Act authorizes the United States Public Health Service to conduct and support research into the prevention and abatement of air pollution, to provide technical assistance, and to conduct and support training in air pollution technology.

It is generally accepted in the United States that responsibility for administration of a programme for the prevention and abatement of air pollution should be at that level of government closest to the problem and which is capable of dealing with it adequately.

In programmes at all levels of government, control is most effectively brought about only by legislation which appears reasonable in the light of technically-substantiated criteria. It provides adequate flexibility, yet is sufficiently specific to meet the needs of the area under consideration.

After analysis of existing air pollution legislation, the Public Health Service, in co-operation with several other interested groups, recently developed certain principles[3] designed to guide States considering new legislation.

State and Inter-state Control 37

Responsibility for the control of air pollution on a State-wide basis usually is given to authorities, boards or commissions created in the State health department. These bodies are authorised to adopt codes, rules, and regulations while enforcement is usually the responsibility of the State health departments acting as their agents.

In addition to State-wide control, other types of State legislation authorise local control, or provide for research and technical assistance by the State. A few States have enacted legislation combining certain features of these three basic types.

Uniform laws and voluntary co-operative agreements have been suggested as one approach to interstate air pollution. Such arrangements, however, are subject to different levels of enforcement in the interested States, and are subject to unilaterial amendment or abrogation with no assurance of continuity of co-operation.

The use of interstate compacts has been suggested as a sounder and more durable legal basis for action on interstate problems. These compacts have the effect of Federal statute and are enforceable by the parties concerned through the Supreme Court.

Regional Controls

In recognition of the importance of the physical and other factors contributing to air pollution, increasing consideration is being given to the air basin or regional approach to the solution of problems. Provision is made for establishing a regional authority authorised to carry out an air pollution control programme without regard to existing lines of local political jurisdiction. An example of this concept is the Bay Area Pollution Control District, which comprises six counties in the San Francisco, California area.

Local Control[1]

Some local areas find their authority to abate public nuisances adequate to cope with the air pollution problem. Many others, however, have found the general " public nuisance " approach ineffective and cumbersome and have enacted specific air pollution control ordinances under authority of the police power delegated to them by the States. More recently, a number of States have enacted general enabling legislation which authorises cities and counties to adopt comprehensive air pollution control programmes and to establish the limits of air contaminants which may be emitted from sources within their jurisdiction.

Most community air pollution control programmes require a permit from the control agency prior to the construction, installation, or alteration of fuel-burning equipment. Upon completion of an installation, an operating permit or certificate is issued. Some local ordinances also require annual inspection and renewal of operating permits for all fuel-burning equipment.

Small fees generally are charged for installation or repair permits, scaled to the size of the unit involved in terms of various parameters. In addition, a number of communities have detailed requirements regulating the purchase and use of specified fuels. Such provisions serve to insure the application of sound engineering principles to combustion equipment. They place important technical and administrative responsibilities upon the control authority and emphasize the importance of adequately trained personnel.

Provision for appeal from administrative action to an impartial hearing board frequently is provided as the final step in agency action before judicial review may be obtained. The appeals procedure furnishes an accepted method of protection against hasty, arbitrary or unduly oppressive administrative action.

Some ordinances authorize the control officer or the hearing board to grant variances, which in effect constitute exemptions from certain provisions of the ordinances for particular sources of air pollution. It is customary to grant variances rather liberally during the initial period of operation of the control programme effective for a limited time.

International[4]

There has also been some consideration of instances of air pollution along the international border between the United States and Canada. By the terms of the Boundary Water Treaty of 1909, between the United States and Great Britain, an International Joint Commission was established to hear and determine disputes arising out of the use of boundary waters. In 1949 the Governments of the United States and Canada referred to this Commission the problem of air pollution from vessels passing through the Detroit River in the vicinity of the City of Detroit, Michigan and the City of Windsor, Province of Ontario. The technical advisory boards assisting the Commission have completed their investigations and recommendations have been submitted. The co-operative spirit demonstrated by the members of the Commission has been of great value in dealing with this problem.

Administration

A recent survey has disclosed total expenditures of approximately 21,110,000 for State air pollution programmes. In State governments, 96 full-time professional and technical personnel and 134 part-time personnel are engaged in air pollution activity.

A study conducted in 1956[5] and a more recent study revealed the wide variation prevalent in local legislative-administrative air pollution control practices.

These studies also revealed that independent air pollution control agencies were supportable only by sufficiently large population groups. Independent agency status is not universal in the larger population groups, however, this fact indicates that there may be advantages in conducting air santitation programmes as part of larger administrative structures, provided programme emphasis is not sacrificed.

Available data[5] has shown that a budget of at least five cents *per capita* is necessary in the United States to provide a minimum of services and more than fifteen cents *per capita* is needed to provide more complete services. Obviously, the quality and quantity of work that an agency can perform are quite dependent on its budget.

While there appears to be some uniformity in air pollution control legislation in the United States, it is also apparent that variations have been incorpoated to meet the specific technical and political needs of the areas subject to such legislation. Experience has shown that this approach holds the greatest promise of success, in view of the many factors which should be considered in the development of control programmes.

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III. 21

THE GROWTH IN WORLD FUEL CONSUMPTION AND ITS THREAT TO CLEAN AIR

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SUMMARY: Population growth and industrial expansion are increasing world energy requirements at over 3 per cent per year. The growth in fuel consumption is accompanied by a slow but significant deterioration of the fuel mined, including with both coal and crude petroleum a rising sulphur content. The use of oil for road vehicles has doubled during the past 12 years. There is also a continuing transfer of population from rural to urban life, leading to larger towns and cities. The outlook for clean air would be depressing but for mitigating factors described—industrial units tend to become larger, with improved combustion control and facilities for gas-washing, etc., and there is an increasing use of refined fuels which, relatively, tend to become cheaper. The incentive to remove sulphur from fuel is increasing, linked with increasing sulphur needs. The world picture for clean air is one of light and shade. Policies are required to harness industrial economic motives and developments with the not less important objective of reducing pollution.

That fuel consumption is a threat to clean air has long been realized in this country. As long as six and a half centuries ago a London artificer was shown to be guilty of polluting the air of the capital by burning coal, and was executed for the offence. Yet when he paid the supreme penalty, and indeed for several centuries thereafter, the amount of coal mined in this country and elsewhere was almost negligible. It is in the last two hundred years that we have had the explosive increase in population and industry that has brought total world consumption of the primary sources of energy (that is, coal, oil, natural gas and hydro-electricity) to its present level of four milliard tons a year of coal equivalent. There is no sign of slowing down, and it is natural that concern should be felt about the rate of this development and the threat it implies to the air we breathe.

Short of a catastrophe, there can be little doubt that energy consumption will continue to grow fast. Upon its doing so depend the ability of nations to feed, clothe and house their multiplying populations and the hopes of all for a higher standard of living. In recent decades the human race has accelerated its rate of growth to some 1½ per cent a year by applying medical knowledge to increase the expectation of life and by maintaining birth rates at a high level. This rate of growth is sufficient to swell world population from its present level of a little under three milliards to one of over five milliards at the end of the century. Industrial production and energy consumption, like population, have expanded at different rates in different countries and the relationship between them has also varied at different stages in each country's history according to whether emphasis has been on the heavy, or the light, fuel-using industries. But taking the world as a whole and covering the sweep of time since the beginning of the present century, it appears that industrial production has grown at an average compound rate of rather over three per cent per annum, and the use of primary fuel, on which it has depended, has averaged over two and a half per cent. As in the case of population, there has been some acceleration in recent years so that during the last two decades, although these have straddled a world war, production has averaged about five per cent a year and energy usage over three per cent. Even if we discount the acceleration and assume simply a continuation of growth at the average speed recorded so far this century, the prospect is that total energy requirements will be trebled from today's four milliard tons of coal equivalent per annum to about 12 milliard tons at the end of the century. Although exhaustion of reserves will affect some sources of energy in some regions, it is not expected to prevent the expanding overall demand for energy being satisfied in one way or another during this period of time.

The growth in fuel consumption is accompanied by a very slow but significant deterioration in the quality of the fuel mined. The exploitation of most minerals usually proceeds by the working, first, of the most accessible and highest-quality deposits and then, as the reserves of these decline, the less attractive resources. As the cost of labour increases, methods of mining become more mechanized. In the case of coal, one of the results of these tendencies is that the percentage of fines, ash and sulphur is gradually increasing. The ash and fines are amenable to corrective treatment in preparation plants, but the higher sulphur content is more serious because the greater part of the element occurs either in organic and virtually indissoluble combination with the coal substance or in the form of very finely disseminated pyrites which are virtually irremovable by washing and froth flotation processes. Over the last two decades the sulphur percentage in British coal has gone up from 1⅓ to 1⅔ per cent; a similar trend is shown by the analyses of their coals made by American public utility undertakings; and concern is expressed in Germany about the sulphur content of Ruhr coals.

Crude petroleum also has a rising sulphur content. In the early days of the United States oil industry the refineries could select their feed stocks from the sweet or low sulphur oils, but even at the end of the last century reports were being issued about the high sulphur content of the oils then being produced in Ohio and Canada. Although some of the sourer crudes now being mined have as much as five per cent sulphur, United States oil as a whole averages about one per cent. But, as in Western Europe, there is increasing dependence on Middle Eastern crudes and these average about two per cent. Substantially all the sulphur is removed from the lighter distillates in the course of refining, and the heavier distillates may have their sulphur content reduced. It is not, however, at present practicable to reduce the sulphur content of the residual fuel oil, and this product now normally contains three to four per cent sulphur. With the increasing use of fuel oil and the probability that more sulphurous crudes will be used, the release of sulphur from this source is likely to increase.

The degree of air pollution resulting from industrialization depends a good deal on the type of industry that is expanding and it is noteworthy that the pacemakers in economic development include many of the trades that present the biggest pollution hazards. The fastest-growing industries are the chemical, metallurgical and engineering trades and also the industries making building materials—for instance, cement. These are the producers of the fertilizers, machines and buildings that are needed to increase agricultural productivity and to make goods for consumption. They attract the largest share of new investment resources, particularly in the less-developed countries, and their growth rates are bigger than those of the textile, clothing, food, drink and furniture trades.

But not all of the forms of economic activity associated with consumption rather than investment have the slower rate of growth. One outstanding exception which makes its distinctive contribution to air pollution, is the use of motor vehicles, particularly passenger cars. The world fleet of motor vehicles has doubled during the last nine years, four-fifths of the addition being passenger cars. The consumption of motor spirit and light oil by road vehicles has not increased quite as fast but has nevertheless doubled during the last 12 years. The fumes from the burning of these fuels are at present exhausted mainly over the roads of North America and Western Europe. But the economic advantages of road transport coupled with the attraction of the motor car as an outlet for higher income mean that other road systems are rapidly developing in the same way.

Another characteristic of the historic process is the increasing geographical concentration of population and energy consumption and, therefore, of air pollution. Economic development consists essentially of the transfer of population from agriculture to industry and from rural to urban life. New factories are generally sited in or near existing centres of population where labour is most readily available, water supplies and transport services are good and there is easy access to markets and sources of materials, equipment and technical assistance. In such favoured locations new growth encourages further growth and the amenities of town life and the higher wages paid by manufacturing industry act as magnets on the population of the villages. At the beginning of the last century only about one in every eighty people in the world lived in a town of 100,000 or more. Nowadays, in the world as a whole, about one person in eight lives in a town of this size and in the more developed countries one in every two does so. This movement shows no sign of being halted and, until it does, it will be realistic to assume its continuation.

So far, the outlook appears depressing but there are fortunately some mitigating features. Thus, the tendency towards geographical concentration of energy consumption just referred to is also accompanied by an increase in the size of the plants which use fuel and, the larger the plant, the more easy it is to secure efficient combustion and to install grit arrestors and dust precipitators and the less difficult the task of removing sulphur from the flue gases. Thus, a typical modern power station burns well over a million tons of coal per annum compared with stations of about half this size being commissioned before the war. The size of the ultimate industrial consumer is also tending to increase because of the economic advantages of large-scale operations in manufacturing industry. A representative modern, integrated iron and steel works has a capacity of, say, two million tons of steel a year whereas a representative pre-war plant was capable of only half this output. Industrial boiler plants are getting bigger. Again, although in some countries it is found advantageous in transport costs to build a number of cement plants near the consuming centres instead of concentrating production in a few giant plants, the cement works with outputs exceeding a million tons a year now to be seen in the United States are distinctly larger than their predecessors.

An important feature of the energy scene is the increasing use of refined fuels by the ultimate consumer. This represents in part a shift in the pattern of primary energy production and in part a greater processing of coal into electricity, gas and coke and other solid smokeless fuels before delivery to the final consumer.

As regards the shift in the proportions of the different primary fuels used, coal production, especially in the western hemisphere and in western Europe, has increased relatively slowly in recent decades. Despite the mechanization of mining it is particularly difficult for the collieries to reduce labour costs per ton as wage rates increase and the reserves in the thicker and more accessible seams dwindle. Just as the cost of wood fuel has gone up, so the long-run tendency is for the price of coal relative to that of other commodities to rise, although there have been notable interruptions in the trend such as the steadiness of United States coal prices during the last decade, when a radical concentration of output in the more efficient mines has been forced on the industry by the sharp competition from oil and natural gas. Although the coalfields constitute by far the greatest reserve of hydrocarbons, which will continue to play a major role as a source of solid fuel and, in the longer run, become a principal source of chemicals and liquid fuels, the immediate prospects are that the increase in coal consumption will be relatively slow.

The use of oil and natural gas and also hydro-electricity is rising so rapidly that these sources are currently carrying the main burden of the expansion in total energy demand. The oil industry reached a total output of 100 million tons in 1890 and doubled this by 1929—that is, in a period of 39 years. The second redoubling was achieved in 19 years and the third redoubling, from 400 to 800 million tons a year, took only the nine years from 1947 to 1956. World crude production is now approaching a milliard tons a year. Although production costs in the older producing fields are tending upwards, the discovery of prolific new reserves, coupled with improvements in extraction techniques and reduction in transport and refining costs, has meant that there has not so far been a sustained rise in the price of oil relative to other commodities, nor is a general exhaustion of oil reserves to be expected during the next few decades.

Natural gas has the sulphur and other impurities removed before it is made available for public supply and is then, next to hydro-electricity, the cleanest of all the primary sources of energy. Its use is increasing at about the same rate as that of oil but it is at an earlier stage of commercial development, accounting over the world as a whole for about an eighth of total energy consumption compared with oil's contribution of nearly a third. So far its main field of exploitation has been in North America but it now appears to be on the threshold of a major expansion in western Europe, the Soviet Union and elsewhere. Its technical advantages, cheapness at source, the development of pipeline and tanker means of transporting it and the fact that the total reserves of natural gas are no less than those of crude oil, give it a great future.

Hydro-electricity is the smallest of the main sources of energy but its average rate of growth in the last few decades has been about five per cent a year. Although it needs large sums of money to develop, the high level of demand for electricity, the existence of a large untapped potential, particularly in some of the less developed regions, and the improvements that continue to be made in the techniques of reservoir construction, give it considerable further prospects. Finally, a start has already been made with the exploitation of nuclear power. The structure of primary energy consumption is thus shifting in the direction of increasing proportions of the more refined forms of energy—liquid, gaseous and electrical.

As regards the greater processing of coal into refined fuels, the proportion, and indeed the total tonnage, of coal used in its raw state is falling while the amounts used as electricity, gas, coke and other processed solid fuels are rising rapidly. In western Europe the tonnage of coal consumed in its raw state by the ultimate consumer has declined by more than a quarter during the last two decades, while the quantity processed has increased by more than half, the most avid consumers being the power stations and coke ovens. The increase in consumption at gasworks and briquetting plants has been slower but considerable importance is now being attached in Britain to the development of new methods of processing coal into solid smokeless fuels suitable for use in domestic grates. In the United States the same movement has been even more striking; the direct consumption of raw coal has been more than halved during the twenty years, the consumption by coke ovens has increased by half and the consumption by power stations has quadrupled. Greater dependence on refined fuels is characteristic of all the main classes of consumer including the domestic sector which is one of the sectors of particular interest to the Clean Air movement because the small sizes of the appliances used in it make it hard to avoid smoke pollution unless smokeless fuels are employed.

It would be complacent to regard the popularity of the refined fuels as mainly due to the need to avoid atmospheric pollution; it is more realistic to ascribe it to factors that have a more immediate economic bearing on consumers. As industrialization proceeds, technology improves and standards of living and wage rates rise; the secondary fuels tend to become less expensive in comparison with the primary and their labour-saving characteristics and efficiency in use to become more appreciated by the consumer. In the United Kingdom and Belgium the price of coal has multiplied during the last two decades by approximately the same factor as wage rates. The price of electricity has increased only about a third as much, which means that for the expenditure needed to buy a given amount of coal or human labour in these two countries roughly three times as many units of electricity can be purchased now as could have been purchased before the war. In the United States, for the reason given earlier, the price of coal has risen less than the price of labour, but there, too, electricity is now three times cheaper in relation to coal than 20 years ago.

The slow upward tendency in primary materials prices relative to other prices also affects clean air in another way. It increases the economic incentive to recover sulphur from fuel. So far this century the cost of sulphur has been held down by the working of the rich American salt dome deposits by the highly economic Frasch process. But these domes are a comparatively rare geological phenomenon and the reserves suitable for this method of extraction are limited. A gradual rise in the cost of brimstone is therefore to be expected. At the same time, the demand for sulphur is rising fast. Sulphuric acid is by far the cheapest acid to manufacture, and either directly or in the form of acid, sulphur is needed to make such sought-after products as fertilizers, chemicals, rayon, metals and refined oil. One way of bridging any gap between demand and supply will be to make greater use of other natural deposits such as those of pyrites, gypsum and anhydrite, extraction from the last two-named being expensive even when combined with the production of cement. The alternative will be to recover more sulphur from metallurgical and fuel-using processes. Recovery of sulphur from smelter fumes can be fairly readily increased, but recovery from fuel consumption is more difficult. The amount of sulphur now being released, however, in the process of fuel consumption must be over 30 million tons a year, or about twice the world's annual consumption of sulphur. From the point of view of clean air it must be a primary objective to develop methods that will ensure that as the pressure on sulphur supplies increases, demand can be economically met by greater recovery rather than by increased mining of mineral deposits.

The world picture is, therefore, one of light and shade. Population, industry—including the heavy investment goods industries—and the energy consumption on which economic development is based, are growing rapidly and their effects on clean air are heightened by the tendency towards geographical concentration of population in large towns. The quality of the coal and crude oil produced—particularly their sulphur content—is deteriorating slowly. On the other hand, the increasing size of the plants in which fuel is used makes it more practicable to limit pollution. Even more important, the growth in primary energy production is mainly in the form of oil, natural gas and hydro and nuclear electricity, while coal is increasingly processed into gas, electricity and smokeless solid fuel before it is supplied to the ultimate consumer. These tendencies reflect changes in price relationships and economic incentives which are themselves the outcome of deep-seated factors such as the advance of technology, the dwindling of the more accessible and attractive mineral reserves and the rise in earnings and standards of living. Similar factors seem to be at work to increase the incentives towards the recovery of sulphur from industrial processes and fuel consumption instead of using more brimstone, although here there is the alternative of increased mining of other minerals such as pyrites, anhydrite and gypsum.

Because of these general factors the threat that growing energy consumption presents is less than might at first sight appear. Nevertheless, it would be wrong to leave it entirely to them to bring about the improvements that are needed in the interests of clean air. Policies are required that harness the more directly compelling economic motives underlying industrial development to the task of furthering the less tangible, but not less important, objective of reducing pollution.

II. 22

FLY-ASH COLLECTION IN PLANT USING SECOND-RATE FUEL

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SUMMARY: In Czechoslovakia, the use of the best coal as raw material for the chemical industry necessitates the use of second-rate coal in power stations. This means that design requirements of dust collectors and electrostatic precipitators in particular are severe. Theoretical calculations and practical measurements were made of the efficiency of electrostatic precipitators. Some results of these investigations are given. For collection of fly-ash from second-rate fuel, the stress must be laid upon the high value of the space-charge density of ions in the gas. A tube type precipitator shows advantages.

Our economic plan provides for the use of first-rate coal in the chemical industry. The second-rate fuel has, therefore, to be burned mainly in power plants.

It is obvious that the use of this kind of fuel results in more severe requirements as far as collecting efficiency of fly-ash collectors is concerned, with respect to the permissible pollution of air. The importance of this problem becomes greater when this coal is burned in pulverized state, because at the inlet of the dust collector the concentration of fly-ash, which is a by-product of combustion, is higher and size distribution relatively fine. In Czechoslovakia such problems are solved by means of electrical precipitators alone, or in combination with aero-mechanical collectors. Another existing solution is the use of wet aero-mechanical collectors. With respect to higher concentration of fly-ash (above 25 g/Nm^3) and relatively fine size distribution, we had to investigate thoroughly the behaviour of electrostatic precipitators. We started with a theoretical analysis which led to the opinion that the relation between the space-charge density of ions in the clean gas, ρio, and the space-charge density of fully saturated fly-ash particles, Σne is of fundamental importance for precipitation as far as the concentration and size-distribution of fly-ash is concerned. The factor for reduction of particle-charges reads as follows:

$$\beta = \frac{\rho_{io}}{\frac{3G}{\pi \gamma} \left(K \frac{E}{2} \int_{Z=0}^{Z=Z_1} \frac{dZ}{\Phi} + 2.10^6 e \int_{Z=Z_1}^{Z=1} \frac{dZ}{\Phi 2}\right.}$$

where:	β	reduction factor (the space-charge of fully saturated particles multiplied by this factor gives the actual value).
	ρio	space-charge density of ions in clean gas.
	G	concentration of ash in gases (by weight).
	γ	specific weight of ash.
	K	loading factor for particles greater than 1μ.
	E	mean intensity of electric field.
	e	the charge on an electron.
	Z	residue factor that represents the fly-ash size-distribution.
	Φ	equivalent diameter of the particle respective to the value of Z.

To prove this theoretical analysis correct we compared a series of measurements on big plants working under different conditions and the respective calculations. The results are in table T-1. It can be seen that the agreement is good enough.

Thus the main question was: What would be the influence of higher concentration and fine-distribution of dust on the total precipitating effect, namely the efficiency?

The answer is in the following figures:

Fig. 1. Residue curves of fly-ash used for theoretical analysis.

Fig. 2. Relation between reduction factor β and fly-ash concentration, for both sorts of fly-ash I and II.

Fig. 3. Relation between collecting efficiency, gas velocity and ash concentration, for both sorts of fly-ash, I and II.

From results of this theoretical analysis of electrical precipitation it is apparent that the collecting efficiency for fine fly-ash particles is lower than for coarse particles, and that:

Table I

Precipitator	*Firing space*	*Fuel*	*Separating % measured*	*Efficiency calculated*	*Inlet concentration g/Nm^3*
I	Melting chamber	Mineral coal average	61·5	60·9	13·5
II*	Granulate	Lignite	80–90	94·3	15·5
III	Grate with additional powdered coal firing	Lignite	92·6	87·8	7·39
		Heterogenous	88·2	83·8	5·20
		Mixed	71·65**	70·0	6·56

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* The greater difference between the two values (measured and calculated) was brought about by the unsteady operation of the boiler during measurements. When calculating, the coarsest granulometric composition of fly-ash was considered. That is the reason why the calculated value is higher than the value ascertained by measurement.

** The low value of separating efficiency was ascertained by measurement at which the applied voltage was purposely decreased. At measurements I and III the boiler operation was more steady than in the case of II.

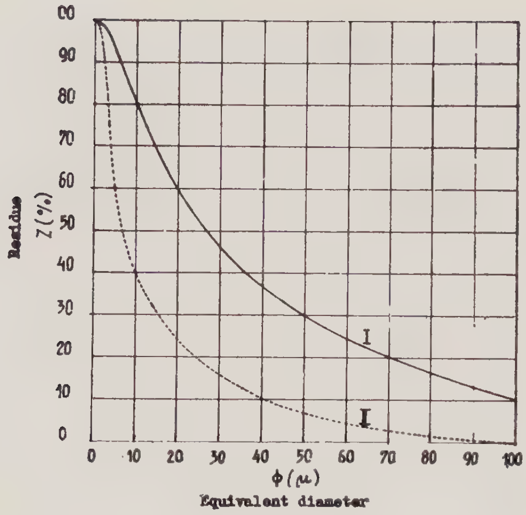

Fig.1

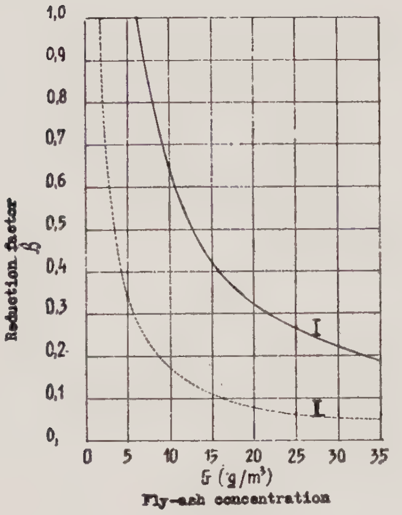

Fig.2.

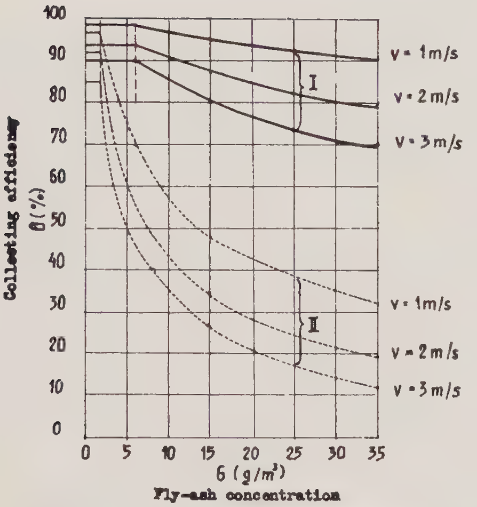

Fig.3.

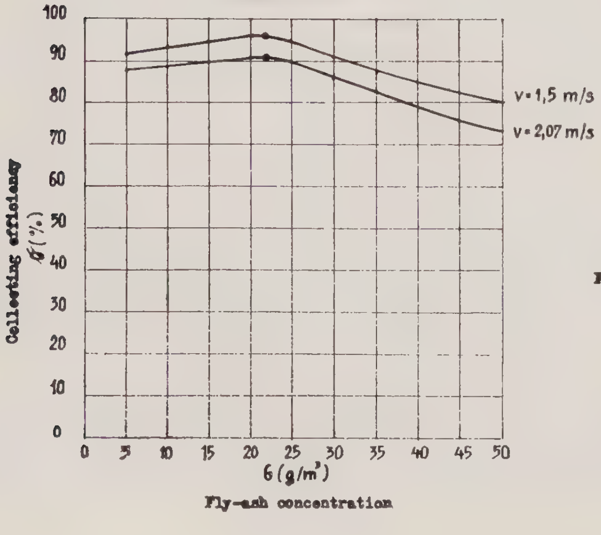

Fig.4.

(1) The collecting efficiency is independent of the concentration up to a certain limit-value of concentration, provided that the gas-flow velocity in precipitator and dispersion of fly-ash are unchanged.

(2) The limit-value of fly-ash concentration, i.e. the value, at which the course of the curve changes from the value independent on the concentration to the values decreasing with concentration, is lower for fine fly-ash dispersion than for coarse dispersion.

(3) In both cases, and for concentrations below and above the limit-value, the collecting efficiency increases with the decreasing gas-flow velocity in compliance with the known functional properties of electrostatic precipitators.

The laboratory verification of these theoretical results were made on a tube precipitator. From results of measurements indicated in Fig. 4 we can make the following conclusions:

(1) The collecting efficiency does not change very much in the range of concentrations below the limit-value. The slightly rising tendency of collecting efficiency in this range is probably caused by coagulation, the influence of which rises with increasing concentration. A quantitative investigation of this coagulation has not yet been made.

(2) The limit-value of concentration is for both characteristics the same (about 22 g/m^3).

(3) The collecting efficiency is higher for low gas-flow velocities than for high velocities.

The residue curve in Fig. 5 determines the size-distribution of fly-ash used for these tests. The limit-value computed is about 10 g/m^3, which is approximately one half of the value determined experimentally. When the influence of space-charge of all particles below 3μ is omitted the limit-value of concentration changes from 10 to 20 g/m^3, and becomes nearly the value determined by measurement (Fig. 6).

Reasons for the apparently great influence of fine particles on the precipitating action are:

(1) Fine fractions increase considerably the space density of particles in gas, in spite of the fact that they are only a small part of the whole quantity of dust load.

(2) The effect of small particles is to contribute, to a great extent, in the production of the space-charge, and their influence on separation is therefore very great.

(3) The large number of particles in these fine fractions increases the number of occasions for coagulation.

These conclusions were verified also on a pilot plate-type precipitator at different values of inlet concentration of fly-ash. The obtained values are in Fig. 7.

Deviations between theoretical and laboratory results are as follows:

(1) When considering very low concentrations the influence of rapping is more apparent, as the amount of particles blown away by the gas-flow is relatively high. Collecting efficiency for very low fly-ash concentrations is somewhat lower than theoretical values.

(2) These tests proved, that in case of concentrations below the limit-value, the collecting efficiency becomes slightly higher with increasing concentration, and again this fact seems to be caused by coagulation of particles.

(3) For concentration above the limit-value, the collecting efficiency decreases with increasing fly-ash concentration in flue-gases to a certain value at which it reaches the minimum efficiency. With further increasing concentration the collecting efficiency begins to rise again.

Final conclusions from these observations cannot be made, but we believe that this work shows clearly why the collecting efficiency is sometimes different.

It is obvious from all these studies, that for collection of fly-ash from second-rate fuel of very high ash-content, the stress must be laid upon the high value of the ions space-charge density of gas, which determines the charge of particles. For this purpose, the solution was carried out, theoretically as well as experimentally, about the possibility of using a tube ionizer followed by plate-type collector. The laboratory experiments proved the theoretical results to be correct and showed that the ions space-charge density in tube precipitator $\rho\Phi$ is several times higher than in plate-type of precipitator $\rho\,\|$. (Fig. 8 gives calculated values and Fig. 9 gives measured values.)

Fig. 10 gives curves K-1 and K-II, corresponding to fly-ash of types I and II respectively, for a plate-type ionizer, and curves Φ-I and Φ-II corresponding to fly-ash of types I and II respectively, and shows the calculated dependence of reduction factor on the concentration. From this figure it is obvious that the advantages of tube precipitator are as follows:

(1) In a tube ionizer, very high space-charge density produced by ions and, therefore, higher charging of fly-ash particles is attained.

(2) The range of concentrations, at which the collecting efficiency is theoretically invariable, is wider, which means that the limit-value of concentration approaches the higher values of concentration.

(3) Naturally, the collecting efficiency is slightly higher in all sections of the curve, i.e. for all concentrations.

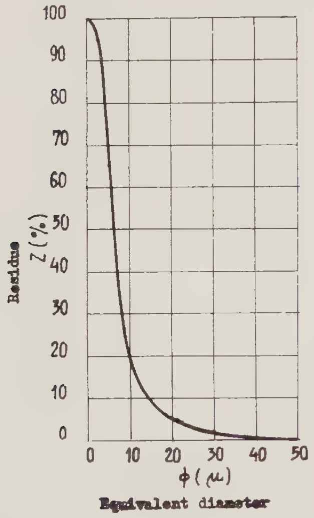

Fig.5.

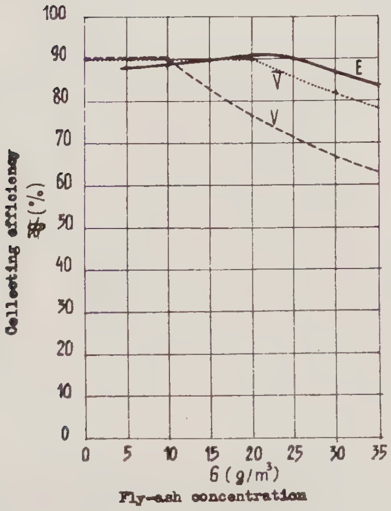

Fig.6.

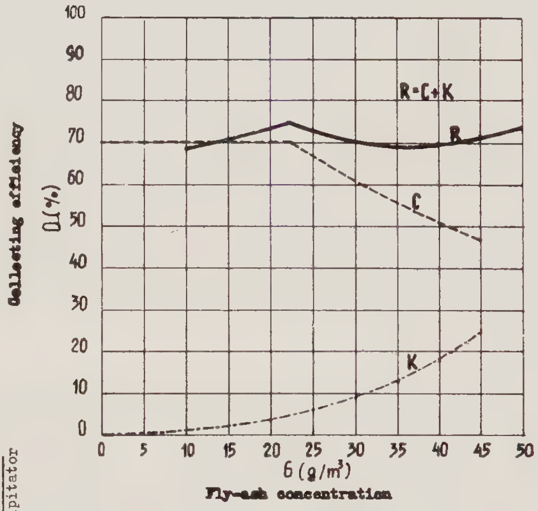

Fig.7.

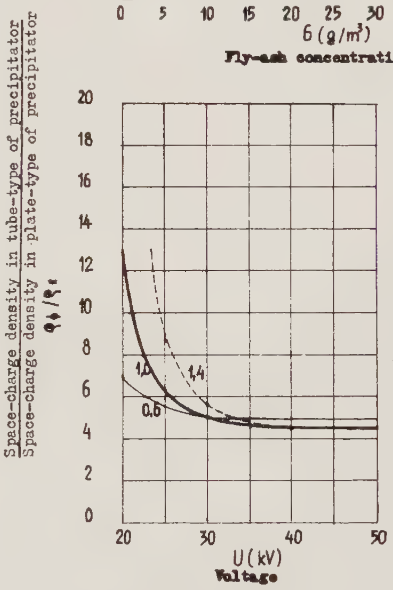

Fig.8

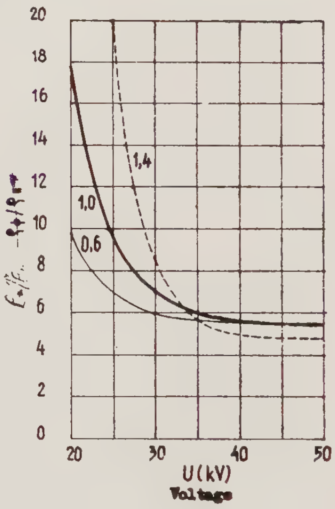

Fig.9.

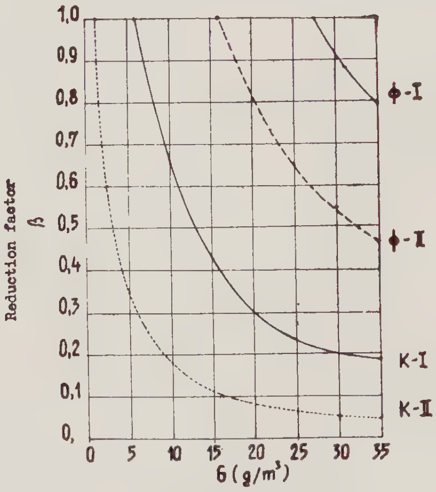

Fig.10.

THE DEVELOPMENT OF NEW SMOKELESS FUELS

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SUMMARY: There are signs of an increasing public demand for "premium," i.e. high grade, solid smokeless fuels. The reason for this increase in demand is convenience. This total convenience is made up of easy handling and storing, brightness in burning and rapid pick-up after refuelling, and a low ash residue which does not blow about. In the short term the increase in demand is being met by adapting traditional plant and methods. New processes are being brought into production to meet the longer-term demand resulting from the Clean Air Act; these processes are more economic and produce a better fuel. The nature of these processes is outlined.

The towns of this country intend to get rid of their smoke: they have public opinion to back them, and the statute book to give them the power to act. The change will be far-reaching, as the Beaver Committee [1] showed; for example, the committee agreed that no fewer than 19 million tons of coal which are burned every year in houses in black areas will have to be replaced. When the committee reported, five years ago, it thus laid bare the size of the change which this country will have to make, but of course it could not forecast how the change would be made—what smokeless fuels the public would choose. An instructive thing that has happened since then has been the movement of public demand for the various smokeless fuels through four successive winters. This is the one piece of evidence that has been added since the Beaver Committee reported: we now see how public demand has begun to change. This evidence of the market-place is beginning to point towards a policy for the development of smokeless fuels.

The one thing that everybody has heard is that householders have been buying oil and paraffin in place of coal. This is, however, a superficial assessment of the change in the habits of householders. What has happened is that householders have already been buying more smokeless fuel, and oil is one of the fuels that they have been buying. Table I gives the sales, in the four complete years since the Beaver Report was published, of the four kinds of smokeless fuel between which the public can choose—that is, electricity, gas, solid smokeless fuels and oil.

The trends in Table I are unmistakable. There has been a firm increase in the household use of electricity and of oil: oil has made the larger gain, having risen over 60 per cent in four years. (The home use of electricity, of course, includes lighting and some power as well as heating.) By contrast, gas and the solid smokeless fuels have at best stood still. From these overall figures, I will draw for the moment only one rudimentary lesson. It is this: that whatever the public has been looking for, it has not been looking for the cheapest smokeless fuel—for the cheapest of these four sources of heat are some of the solid smokeless fuels.

There are more subtle lessons hidden in Table I and, in order to find them, we must look to see how its figures are made up. Electricity is all one kind of fuel, and so is gas one kind, and oil that is used in the home is in the main of two kinds only. But the solid smokeless fuels are less homogenous both in use and in quality. First, there are smokeless fuels that are burned mainly in closed stoves, and there are others that are burned mainly in open grates—either in stool-bottom open grates or in improved modern open grates. Second, for each of these uses there are fuels of different qualities, which offer the householder different amenities in addition to the crude heat which they give out. I am concerned in this paper only with premium fuels of high quality, and therefore I shall extract from the total figure for solid smokeless fuels in Table I the figures for the sales of the premium fuels. In Table II, I present the sales of premium fuels for the open fire in the four years since the Beaver Report was published, and in Table III I present the figures for the sales of premium fuels for closed stoves in the same years.

The figures in Tables II and III are striking. For Table I seemed to show that the sales of the solid smokeless fuels in the last four years had been stationary; but now we see that there has in fact been a first movement in public demand. The sales of all the premium smokeless fuels, for the open fire and for closed stoves, have been rising quite rapidly. The percentage rise in the sales of premium fuels for the open fire in four years has been over 70 per cent. This is greater than the rise in the household sales of oil, and is the largest rise of any smokeless fuel.

We must not read too much into Tables II and III—or, for that matter, into Table I, in which the oil figures have hitherto had all the public attention. The quantities of smokeless fuel which are being sold are still quite marginal: less than a million tons of premium fuel for the open fire, 1·3 million tons of oil (equivalent to 2·2 million tons of coal in heat content), and just under 2 million tons of premium fuel for closed stoves. Neither singly nor in total do these quantities compare with the 30 million tons of house coal that is sold. Moreover, we have not yet felt the impact of the Clean Air Act in any force: the main body of local legislation to forbid the making of smoke will come some years from now. Therefore the changes which Tables II and III record are voluntary changes; they represent the choice of consumers who are free to choose, and who on the whole can afford to choose what they like best.

Nevertheless, we must accept the evidence of Tables II and III as the first expression of a deliberate choice by a part of the public. This part of the public prefers the premium fuels, in closed stoves and in open grates. What is important here is not the absolute quantities that it has been buying, but the increase in these quantities from year to year; in effect, this part of the public has been buying each year as much of the premium fuels as it can get. And in doing so, it has not been deterred by their price. Some of the premium fuels which have recorded the largest rise in sales cost in London £12 a ton and more, which works out at more than 10d a therm. Of course the heating bill is a small item in the household budget—it is the smallest single item in the official estimate of the cost of living. Nevertheless, these consumers could keep their heating bills lower by using other than premium fuels; and it is therefore striking that they

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[1] Report of the Committee on Air Pollution (Chairman: Sir Hugh Beaver), November 1954, H.M.S.O. (Cmd. 9322).

Table I
Sales of Smokeless Fuels for Household Use from 1955 to 1958

Fuel	1955	1956	1957	1958
Electricity (TWh)	20·0	22·4	23·4	26·6
Gas (million therms)	1,361	1,347	1,310	1,320
Solid Smokeless Fuels (million tons)	5·6	5·6	5·2	5·6
Oil (million tons)	0·8	0·9	0·9	1·3

Table II
Sales of Premium Smokeless Fuels for Open Grates from 1955 to 1958

Fuel	1955	1956	1957	1958
Premium Smokeless Fuels for Open Grates (in thousands of tons)	468	496	568	788

The premium fuels listed include Coalite, Rexco, Cleanglow and Phimax.

Table III
Sales of Premium Smokeless Fuels for Closed Stoves from 1955 to 1958

Fuel	1955	1956	1957	1958
Premium Smokeless Fuels for Closed Stoves (in thousands of tons)	1,616	1,767	1,794	1,922

The premium fuels listed include Anthracite, Phurnacite and Welsh Dry Steam Coal.

should, in large numbers, have begun to move to the premium fuels year by year now.

At least a part of the public has been expressing preferences which are not dictated by price, and which must therefore reflect something else; something which it calls, in the most general way, convenience. That word has become something of a catchword, and it is important to analyze what this public finds convenient. It seems to me that there are three phrases of convenience in a solid fuel. It must be convenient before we burn it—that is, convenient to handle and to store. It must be convenient when we burn it—that is, in an open fire it must ignite easily, burn brightly and long, and pick up well whenever the fire is made up; and in closed stoves it must burn steadily for long periods and also pick up well. And it must be convenient after we burn it—that is, there must not be much ash and what there is must not fly about. This analysis of what is meant by convenience is not as subjective as it may seem, for it finds support in the qualities of the premium fuels whose sales make the upward trend of Tables II and III.

First, a fuel is most easily handled and stored, and the number of times that the fire has to be refuelled is reduced, if the fuel is dense. No fuel now being manufactured for the open grate meets this requirement. But the position is different among fuels for the closed stove. There, the premium fuels (and only these) are dense, with bulk densities of 45 lb per cu ft and over. It is these dense premium fuels which, Table III shows, have increased their sales for closed stoves.

My second criterion of convenience concerns the performance of the fuel: it must burn well and long and, what is important, it must pick up quickly when the fire is refuelled. In addition, if the fuel is meant for the open fire, then it must light easily in the first place. In all these respects, the premium fuels are exemplary, and Tables II and III show that there exists a growing public which appreciates these merits. Moreover, the premium fuels are very consistent in their performance in these respects, from one consignment to another—and in the case of some of them, such as Phurnacite, from one piece to another.

My third criterion is convenience after the fire has burned out, and this is measured by the amount of ash left behind and by its nature. Here again, the premium fuels for the open grate and for the closed stove have a high standard. The premium smokeless fuels contain 7 per cent of ash or less—some of them much less. This low ash content has, in addition, a marked effect on the performance of the fuels on the open grate, which almost always falls off sharply when the ash content rises beyond 7 per cent.

In summary, what I have tried to show so far is this. There exists a rising demand for solid smokeless fuels of premium quality. In absolute terms, the demand for these fuels is still marginal, and the public for them small; but it has been a growing public year by year since the Beaver Report was published. This public is discriminating, and the fuels that it has been buying have had to satisfy fairly strict criteria of convenience: convenience before use, in use, and after use. A policy to develop new smokeless fuels should therefore take account of these indications of public preference. If new fuels are to reach the widest public which can be foreseen some years from now, when the Clean Air Act will become general, then of course they should be reasonably priced. But they should also incorporate those factors of convenience which have begun to show their appeal to a growing public: briefly, they should be dense, reactive on the open fire, and clean.

The main effect of the Clean Air Act is still some years away: we may estimate that it will be very substantial by 1965 but will not be felt fully until 1970 or later. The development of new smokeless fuels to meet this demand is therefore a long-term undertaking; in the long term, we have to prepare to replace up to 19 million tons of household coal. But there is also a short-term problem between now and 1965 which is pressing.

In the short term we must improvise: that is, we must use existing plants to make the best fuels that we can, even though these plants were not designed to make premium fuels. Both the National Coal Board and the Gas Council are already doing this. Two of the premium fuels which I have listed in Table II, Cleanglow and Phimax, are in effect improvisations by which premium fuels are made in existing gas retorts. Their production began only two years ago and has been successful.

In the same way, the National Coal Board has made Warmco, a new fuel which is not listed in Table II because its production began only in 1959. Warmco is a premium fuel which is produced in existing coke ovens by under-carbonizing a coking coal which has been specially cleaned. Thus Warmco is clean, with little ash, and it burns brightly and lastingly on any kind of open fire, and picks up well. It is one of the denser of the existing manufactured fuels for open grates, but even so it is only just over half as dense as coal. The National Coal Board expects to produce 170,000 tons of Warmco in 1959 and this is, by any standard, a large output in the first year of a new fuel.

Nevertheless, processes of these kinds cannot offer a permanent solution for the production of smokeless fuels of high quality. The plants which these processes use were designed for other purposes, and making premium fuels in them is essentially an improvisation. As an improvisation, it is admirable and necessary, but to treat it as a long-term solution is to condemn ourselves to a static technology. For example, we cannot hope to make a dense smokeless fuel for the open fire in existing plants, and this in itself would bar progress towards better fuels. But above all, there are economic reasons why we cannot improvise indefinitely the making of premium fuels in existing plants. These plants have a low throughput, which means that they are now very costly to build. For example, new coke ovens cost about £9 per ton/year of coal input, which makes a cost of about £12 per ton/year of solid fuel output, or £18 per ton/year of solid fuel of the sizes preferred for the open grate. Capital charges on this scale would impose a heavy burden on the economics of making Warmco, for example, if new ovens had to be built specifically for its manufacture.

If we are to give the public premium fuels for the open fire in quantity and at reasonable prices, then we must approach the problem of coal processing in a radically new way. A new technology is needed to work from those coals which are plentiful today to those fuels which the modern public wants, and to do so economically. This new technology must satisfy three conditions. It must be low in capital cost and high in throughput: to this end, it must use the techniques of modern chemical engineering. It must use those coals which are plentiful today, that is, small coal with a high content of volatile matter—and yet it must get a high yield of solid fuel from this gassy coal. And finally, it must make what the public wants, a convenient fuel which is dense, which burns well and picks up well, and which does not leave a bulky fly ash.

The National Coal Board has carried out detailed research to meet these three basic conditions for some years. I will describe fully one of the new processes which our research has produced, and which the National Coal Board is now developing, in order to show in detail how these conditions are met.

The process which I shall describe takes a powdered coal and blows hot air through it at a temperature between 375°C and 450°C. When air is bubbled through a powder in this way, the mixture moves and flows like a liquid, and can therefore be handled easily; this is the physical advantage of this method of treating solids in what is picturesquely called (because of the way in which the mixture flows) a fluid bed. The chemical advantage of the method is that it allows hot air to reach every particle of coal at the same time, and therefore the time of treatment is short and the throughput of the plant is high. In the fluid bed, we expose the coal to the hot air for less than an hour; a coke oven may treat its charge for as long as 20 hours.

I have already said that we work at temperatures between 375°C and 450°C. These are low temperatures, and they drive off only part of the gas in the coal; whereas the coke oven, working at high temperatures for a long time, drives off almost all the gas. Starting with a coal which has a content of volatile matter over 40 per cent, we make in the fluid bed a coal powder which is only partially coked—what we call a semi-coke or a char—and which still contains about 25 per cent of volatile matter. This high residue of gassy matter gives our process two advantages. In the first place, we have a high yield of hot char—85 per cent of the dry coal that went into the fluid bed. And in the second place, when the char is compacted, we have a lively fuel which burns with an attractive flame, and which is particularly quick to pick up when new fuel is put on after the fire has died down.

On two grounds, then, it is an advantage to leave 25 per cent of volatile matter in the char that comes out of the fluid bed. But the obvious question is, Will such a char be smokeless? A coal which contains 25 per cent of volatile matter is not smokeless. The performance of semi-cokes or chars with a residual of volatile matter had already been studied by Piersol,[2] who had shown that they could be smokeless. Our research work carried on this study in the special setting of the fluid bed, and showed that under these conditions char can be made smokeless (with a content of 25 per cent and more of volatile matter) consistently from a wide range of coals. Thus the technical process rests on a scientific foundation—on the elucidation of the steps, quantitatively, by which gas is driven off from a smoky coal. The scientific finding is that, when we begin with a coal with a content of volatile matter over 40 per cent, the first 15 per cent or so which is driven off is the smoky constituent.[3] The 25 per cent or so of gas which is left behind at this stage is not smoky, and therefore a char made in this way is smokeless yet burns with a bright flame.

The char that comes out of the fluid bed is a powder which must be compacted into lumps if it is to be used on the open grate. To do this, we use one or other of two new technical processes which we have devised. Either we compact the char with a compound binder consisting of a mixture of raw coal and pitch: at 400°C or so, this mixture also retains no smoky parts. Or we compact the char directly in a special press without a binder, using its own plasticity to give it coherence: this press is an application of the Shape process of binderless briquetting to which our research has given much attention. In either case, we turn all the char into dense briquettes, which resemble charcoal in appearance and in the flame they give. Thus, by making char first and then briquetting it, we do not lose any breeze or waste, as most other processes which make premium fuels do. Any fines and broken briquettes can be crushed and returned to the process for briquetting again.

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[2] R. J. Piersol, Rep. Invest. Ill. Geol. Surv. No. 41, 1936.

[3] W. N. Adams, A. F. Gaines, D. H. Gregory, G. J. Pitt, Smoke Emission of Low Temperature Chars, Nature, Vol. 183, 1959. Also D. H. Gregory and W. N. Adams, Smokeless Fuels from High Volatile Coals—I, and A. F. Gaines and G. J. Pitt, Smokeless Fuels from High Volatile Coals—II, Int. J. Air Poll., Vol. 1, 1959.

There is another process to make a premium fuel which the National Coal Board is developing, to which I will refer more briefly. In this, coal is briquetted first, and it is then exposed to moderate heat in an oxidizing atmosphere for some hours. The temperature and the time of exposure depend on the coal, and an exposure of 1 to 2 hours at 200°C to 300°C suffices for most coals. The chemical effect of the treatment is complex, on the coal and on the binder; in part it is a slight desmoking of the kind that I have already described, and in part it is an oxidation and a polymerization. It results in making smokeless briquettes in which the content of volatile matter may be 35 per cent, and once again it gives a yield of whole briquettes without waste.

I have stressed that the mechanics of briquetting play an important part in these processes, and we have spent much research on them. It would take me too far to describe this important work which makes it possible to compact many coals and chars without a binder. Here I want to say only that our research work on the Shape process of binderless briquetting, and on other new briquetting processes, has been basic in enabling us to make premium fuels from coal which is cheap and plentiful—that is, from small coal. Briquetting has an essential place in the development of the complete processes which I have described.

I have described two new premium fuels which the National Coal Board is developing: first, briquettes made from a char which has been made in a fluid bed, and second, briquettes made from coal which are subsequently treated by mild heat. Both these fuels, the char briquettes and the heat-treated briquettes, have been made only in experimental quantities of some tons, and the properties of the fuels in commercial production can only be established with certainty when pilot plants have been built to make them. Nevertheless, I will give, with some caution, figures for the performance of these experimental briquettes in Table IV. In this Table, the fuels have been tested according to the procedure laid down in the British Standard specification for fuels to be burned in modern improved open grates. I have also included in Table IV figures for the performance of the other new premium fuel which the National Coal Board is already producing, Warmco. It will be seen that our aim is to make fuels whose performance on the open fire will be outstanding. This should kill the lingering belief that the open grate is moribund because it cannot give a cheerful fire unless it smokes; on the contrary, the open fire can burn brightly and yet give out no smoke. The char briquettes and the heat-treated briquettes also satisfy the other two criteria of convenience that I laid down: they are clean, and they are much denser than any other premium fuel. Experimentally, we make char briquettes to a bulk density of at least 35 lb per cu ft, and heat-treated briquettes to a bulk density of over 40 lb per cu ft.

These considerations will make it clear that the research programme of the National Coal Board over the last years has been well conceived to meet the demands of a more discriminating public, and the changing supplies of coal, both of which we anticipated. The Board has now formulated a full development programme to put its research findings into effect. Two substantial pilot plants for two different processes are now contracted for, and are expected to produce the first commercial samples of our new fuels to test the public response in the winter of 1960 to 1961. One of these plants is being constructed at Birch Coppice in the West Midlands Division to make char in a fluid bed and briquette it, on a pilot scale of about 5 tons an hour. The other is being designed to heat-treat briquettes made from coal on the same scale, probably at Graigola in the South Western Division.

I will remind you that the National Coal Board already produce a number of premium smokeless fuels, among them natural Anthracite and Welsh Dry Steam coals, Phurnacite and, for the open grate, its new product Warmco. The Board propose to continue to take a share of the market for such smokeless fuels as are required to make the Clean Air Act effective. It proposes to be guided by public demand, and to include fuels of the highest quality made by its new processes. It is the Board's policy to prove these new processes technically and commercially before 1965. The Board believe that this will require an annual rate of production of at least one million tons a year of the new fuels before 1965. It is at present impossible to predict total production beyond 1965, because the market acceptability of these new fuels at the price at which they can be sold economically has still to be proved. This is one of the prime objectives of the pilot plants with whose development I have been charged by the Board. It is the Board's intention to put itself in a position before 1965 to be able to expand production from these pilot plants to full commercial scale at the quickest possible rate justified by market requirements.

In carrying out this policy, the National Coal Board is not backing a single new fuel or a single new process. On the one hand, the new processes have still to be tried in competition with one another and with existing processes. On the other hand, the Board believe that in fact there is a variety of new fuels needed to satisfy the requirements of clean air, and to use those coals of which there is a good supply in different parts of the country. The Board's new fuels are not likely to prove equally acceptable for all purposes, and the scope of each will only be discovered by active development and manufacture on a limited scale, and this is now under way.

A last word about the cost of these developments. I estimate that commercial plants to use either of the two main new processes which I have described will cost less than £7 per ton of yearly output of fuel. The National Coal Board's intention of reaching an annual rate of production of at least one million tons a year by the new processes in 1965 commits it, therefore, to an expenditure approaching £7 million for completed plants. In addition, if public demand is seen to be rising before 1965, we have to expect that an investment about as large again is likely to be committed in plants under construction. To this must be added the cost of pilot plants and other development work. Thus, the National Coal Board will invest in its new processes for premium solid smokeless fuels a sum which is expected to reach £10 million by 1965, and which may approach £20 million.

The public demand will not be all for premium fuels, and the present premium fuel demand is only a fraction of the total fuel demand. In the nature of things, premium fuels are dearer than others and, whatever their convenience, there is a resistance to paying the enhanced price, and the market for the cheaper smokeless fuels will continue for a long time. However, some of this price resistance is short-sighted, and has failed to calculate the realities of the household budget. The additional convenience and the higher thermal efficiency achieved with premium smokeless fuels are cheap. I have already remarked that heating is an exceptionally small item in the national average household budget: in fact, heating and lighting together account for only 5½ per cent (the smallest single item) in the index of the cost of living. The cost of house coal at London prices is approximately 8d. per therm, and the cost of premium fuels for the open fire at London prices is approximately 10d. per therm. Therefore if all households in the country, outside the black areas as well as inside them, were to change from coal to premium smokeless fuels for the open fire, their fuel bills would increase by one quarter, and this would raise the index of the cost of living by less than one point only. The bill for premium fuels, once the public gets the taste for them, is not high.

Nationally, the cost of eliminating the smoke of the open fire is not high. Yet if we are to stimulate the demand for these fuels, and to take advantage of the movement which has begun to show itself in the last four years, we must surely keep the cost as low as possible. This is why I have laid stress on new fuels made by new processes in new plants. The production of smokeless fuels needs as modern and scientific an approach as that of oil and electricity. We need to apply all the methods of advancing technology: to use our most plentiful coals, to process them by continuous methods with a high throughput, and to get a high yield of solid fuel which meets the demands of a discriminating public for dense, free-burning and lively fuels which are smokeless in the air and clean in the grate. Only if we fulfil these precise conditions will we compete with electricity and oil with lasting success. I believe that the development work of the National Coal Board in the field of solid smokeless fuels conforms to these fundamental standards of technical and economic progress.

Table IV

Performance of Warmco and Two Kinds of Experimental Smokeless Briquettes

(Tested by the procedure of British Standard 3142 : 1959)

		Warmco	*Experimental Char Briquettes*	*Experimental Heat Treated Briquettes*	*British Standard requirement for*	
					Type L coke	*Type M coke*
Bulk Density	lb./cu. ft.	24	38	41	under 23	over 23
Time to reach 200 B.t.u./sq. ft. h. after ignition	min.	33	23	28	37	45
Time to reach 350 B.t.u./sq. ft. h. after ignition	min.	57	35	42	—	—
Time to reach 350 B.t.u./ sq. ft. h. again after first refuelling... ...	min.	24	15	29	—	—
Time to reach 350 B.t.u./sq. ft. h. again after second refuelling ...	min.	27	15	32	—	—
Peak radiation after ignition	B.t.u./sq. ft. h.	590	569	575	400	400
Peak radiation after first refuelling	B.t.u./sq. ft. h.	750	764	611	450	400
Peak radiation after second refuelling	B.t.u./sq. ft. h.	749	783	616	325	300
Average rate of radiation	B.t.u./h.	9,690	10,030	8,640	—	—

The tests recorded in this Table have been carried out in the same laboratory under similar conditions, and the results are comparable among themselves. The test procedure used is that laid down in British Standard 3142 : 1959—Manufactured Solid Smokeless Fuels for Household Use. Part 1 : Cokes for Domestic Open Fires. This is the only British Standard specification for the performance of smokeless fuels which exists at present.

THE COKING INDUSTRY: ITS PROBLEMS AND ITS CONTRIBUTION TO CLEAN AIR

R. L. COOPER, M.Sc., Ph.D., A.R.I.C., British Coke Research Association, Great Britain.

SUMMARY: The coking industry is one of the main coal consuming industries in Britain. The coking process itself cannot be operated smokelessly within the normal requirements of the Clean Air Act, by methods that are reasonably practicable economically and technically. It has therefore been placed under the control of the Alkali Inspectorate. The chief source of offence is the coke oven battery. Smoke and dust are mainly given off during charging of the battery with coal, during discharge of the coke, and during the quenching of the coke with water. Methods are described by which the nuisance from each of these processes may be alleviated.

As one of the main coal-consuming industries in this country, the coking industry is giving serious consideration to the problem of atmospheric pollution, both nationally through the British Coking Indutsry Association and the British Coke Research Association and also at certain individual plants. The British Coke Research Association has a small team which is collecting information, participating in investigations of common interest to the industry and also carrying out a limited amount of independent research to fill some of the gaps in our information.

There are about 70 coking plants in this country, owned by the National Coal Board, the iron and steel industry and independent coke producers, whilst two plants are operated by the gas industry. Each year, these plants carbonize some 27 million tons of coal, produce about 18 million tons of coke, of which some 14 million tons are supplied to blast furnaces and foundries as metallurgical coke, and make 200,000 million cubic feet of gas, of which nearly 80,000 million cubic feet are delivered to the gas industry. Thus the iron and steel industry has a predominating influence on the coking industry, although the domestic consumer is also provided with solid smokeless fuel and a large amount of gas. As Lee and Graham* have recently commented, there is every indication that the process of making hard coke will continue in its present form for the next two decades or longer, so that the mitigation of smoke and dust from these plants must be considered in relation to present methods of carbonization rather than to any future modified form.

The Clean Air Act applies to parts of the coke-oven works in the same way as it applies to any other premises in which coal is processed or carbonized. It is recognized, however, that the coking process itself cannot be operated smokelessly within the normal requirements of the Act, at any rate, not by methods that are reasonably practicable, economically and technically, in the present state of knowledge. In common with a number of other difficult processes in industry, the coking process has been placed in a special schedule restricting the application of the ordinary provisions of the Act. This does not mean that smoke may be made *ad lib*, but that the position at the coke-oven works will be judged by an independent and expert body, namely the Alkali Inspectorate, which will concentrate its attention on these particular processes with the object of transferring them to the ordinary provisions of the Act as soon as is practicably possible. The coking industry is very much aware of the activities of the Inspectorate in this respect.

The focal point of the coke-oven works and chief source of offence is the battery. This is a rectangular block assembly of refractory brickwork consisting of between ten and perhaps sixty ovens disposed side by side and separated from each other by walls containing flue systems in which gas is burned for heating the ovens. Each oven is a slot-type chamber about 40 feet long, 12 to 14 feet high and about 16 in. wide, and will carbonize up to 16 tons of coal in a period of 16 to 18 hours. At the end of this period, the doors at each end are removed and the coke is pushed out into a slowly moving coke-car which transports it to a quenching station where it is cooled by water sprays. The sequence of charging the oven with coal and discharging and quenching the coke is carried out for each oven in turn according to a strict schedule, so as to achieve continuity for the battery as a whole. The chief sources of smoke, grit, and dust are associated with these operations, as described below.

When an oven is to be charged, a number of lids (usually four) are removed from the oven top, revealing charge holes. A charging-car, fitted with coal hoppers and travelling on rails along the top of the battery, is positioned so that the outlets from the hoppers are centred over the holes. The coal is in a finely divided condition and when it is discharged into the empty oven it meets the hot surfaces of the brickwork, causing a rapid evolution of gas and smoke, not all of which can be taken into the gas-collecting main which leads off from the oven, despite the help of steam injectors provided for the purpose of suction. The excess escapes to the atmosphere in the form of a dark smoke. During carbonization, and especially in the early stages, smoke may leak out of the oven doors and also through the brickwork of the oven walls into the flues and thence into the chimney which removes the burnt flue gases to the atmosphere where dark smoke again appears. This latter condition is usually associated with older coke-oven plant where the brickwork has been loosened.

At the end of the coking period, the oven is disconnected from the gas-collecting main, the doors at each end are removed and the red hot coke is discharged, by means of a ram through a coke guide into a coke car, creating smoke and dust as it falls. The oven doors are then replaced, the oven is re-charged and the process repeated. Meanwhile, the car containing the hot coke passes to the quenching station where a controlled amount of water (amounting to several tons) is sprayed on to it. This operation gives rise to a plume of grit-bearing steam which leaves the chimney placed above the quenching station and rises into the open air. The handling of coal and coke in bulk also gives rise to dust nuisance at the coke-oven works.

It would be inappropriate here to describe in detail the investigations now being made with the object of minimizing the emissions of smoke, grit and dust from coking plants, but a few examples may serve as an illustration. The British Coke Research Association's team is studying the nature of the pollution so that the sources can be identified more closely and their relative importance assessed with regard to such matters as nuisance potential, dispersion characteristics, and possible danger to health, and also so that more shall be known of the physical and chemical properties which may lead to abatement of the pollution. Factors already known to influence the amount of smoke evolved during charging include the following:—

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*Air and Water Pollution in the Iron and Steel Industry. Iron and Steel Institute, Special Report No. 61, pp. 51–55 (London 1958).

The nature, moisture content and degree of fineness of the coal;
The rate of discharge of the coal from the charging car;
The sequence of operations involved in charging;
The capacity of the gas-collecting main and the degree of suction provided by, e.g. steam injectors;
Working conditions on the oven top and the team work of the personnel.

These factors are in turn influenced by others. For example, the rate of coal discharge is affected by the shape of the hoppers on the charging car and the use which may be made of vibrators or other mechanical feeding devices. More important is the ease with which the gas which is rapidly evolved is taken into the collecting main. Although single collecting mains are commonly installed the Alkali Inspectorate has frequently advocated the use of two collecting mains, one on either side of the battery top, to give additional capacity for dealing with the initial evolution of gas. Many plants, especially the more modern ones, have been equipped with these double collecting mains, but there is some doubt in the coking industry as to whether the high additional capital expenditure, (which may be more than £100,000 for a plant processing more than 2,000 tons of coal per day) is justifiable in relation to the degree of smokelessness achieved. Moreover, double collecting mains are said to make working conditions for the men on the battery top more arduous by increased heat and additional duties, and the question has arisen whether there might not be some other answer to the problem by, perhaps, modification of procedure. In view of the present uncertainty it has been agreed to form a Joint Working Group of the Alkali Inspectorate and the British Coking Industry Association to assess the relative merits of working with single and double collecting mains with reference to smokeless charging and in relation to other factors. The time of writing is too early for any definite conclusions to be stated, and the subject is too complex to discuss here. It is sufficient to affirm that the matter is being pursued with vigour.

The British Coke Research Association has also given attention to the general subject of working conditions on the battery, the concern being with the discomforts involved in the hot, difficult, dirty and dusty operations. Improvements in this direction are no doubt of very great importance in encouraging personnel to give attention to detail, efficiency and cleanliness, and so to reduce smoke emission to a minimum. Importance is attached to good team work, whereby unnecessary emissions of smoke can be avoided. The cleaning of oven doors, ascension pipes and the oven top, and replacement of charging-hole lids, are operations where good team work and favourable working conditions are of paramount importance in reducing smoke.

One further example will suffice. A potential source of complaint is the grit arising from the coke-quenching process. The removal of this grit from the steam is the subject of active investigation within the industry. Experiments have been going on for some time at a coking plant in South Wales with a quenching tower which has been provided with subsidiary sprays above the main quenching sprays. These subsidiary sprays direct water on to wire screens situated just below them so as to provide a curtain of water through which the rising steam must pass. These screens also induce changes in the direction of steam flow, which further assists in removing the entrained grit. Similar work has been going on at a coking plant in North-east England, this time using an installation of inclined asbestos-board baffles. The British Coke Research Association has recently built a full-scale experimental coke oven plant, the quenching tower of which is fitted with a wooden grid arranged so as to give changes in the direction of flow of the rising steam. The effectiveness of this is now under investigation, but it is too early to state with confidence that the problem has thus been solved. The extremely high rate of steam evolution and the necessity for low resistance by any means of trapping the grit presents a major difficulty.

In addition to the mitigation of smoke, grit and dust in the coking industry, certain other aspects of air pollution are also being investigated, in conjunction with the Alkali Inspectorate. These include the problem of sulphur gases, but the details need not be elaborated here.

Neither must we forget the industry's positive role in the clean air programme. In common with other producers of solid smokeless fuel and combustible gas, the coking industry is already making an important contribution in the domestic field to the cleanliness of the atmosphere, and the increased use of smokeless fuels will go much of the way towards this desirable end, although there is still much to be done in educating the domestic consumer to accept the inevitable changes. Popular misconceptions must be removed: the consumer must appreciate the simple fact that 1 cwt of coke will give more useful heat than 1 cwt of coal, that coke is coal with the smoke, but not the goodness, taken out of it, and that coke does not produce more " fumes " than does coal. Complacency, too, must be removed: why should we, in what we like to think of as a modern age of enlightenment, continue to accept dull and dirty surroundings, persistent smoky fogs, wanly sunlit streets and all the extra washing and cleaning that result from air polluted by the smoke we ourselves throw out of our domestic chimneys? The National Health Service would benefit materially from a reduction in chronic bronchitis, pneumonia and even lung cancer if the air in our cities and towns were cleaner. On the national level, expenditure on clean air can be regarded as an investment, which will later be repaid with interest in terms of health and prosperity.

In conclusion a reference to another financial aspect is perhaps permissible. If an industry, such as the coking industry, which is already contributing to the clean air programme by supplying smokeless fuels, should find it necessary to spend money on devices to mitigate pollution at its own plant, it does not seem unreasonable that assistance should be provided in some form of tax remission. Indeed, this was mentioned in the Report of the Beaver Committee on Air Pollution which formed the basis for the Clean Air Act and would correspond to the financial assistance being offered to the domestic consumer who has to alter his appliance in the same interest.

III. 25

A COMMENDED SOLUTION OF THE PROBLEM OF AIR POLLUTION

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SUMMARY: The author suggests various methods which could be used to deal with the main sources of pollution. Motor vehicle pollution could be dealt with by de-sulphurization of oil, the fitting of various cleaning devices, sealing engine components, and revocation of offenders' licences. Technical means exist for dealing with industrial pollution, and industrialists should not consider them a charge on the industry, as, often, they enable some economy to be made. District heating is a possible solution. There is a need for more green spaces in built-up areas. There is also a need for an international convention.

Introduction

It is no longer necessary to set out the inconveniences, risks, and injury caused to living beings and to property by pollutants of the atmosphere. It is also well established that the causes of pollution can be classified in three fundamental groups:

(*a*) The circulation of motor vehicles;
(*b*) Industry and large undertakings;
(*c*) Private dwellings.

Motor vehicles

The problem of pollution of the atmosphere can be solved technically and economically by equipping vehicles with appropriate apparatus and by standardization of fuels for the use of which they are intended.

The first question which presents itself is the desulphurization of petroleum products. These contain, according to their origin, an assessment of from 3 to 6 per cent of sulphur, the combustion of which releases to the atmosphere large quantities of sulphurous gas. The combination of this with the moisture of the air produces sulphuric acid. I need not dwell on the serious consequences which result, nor on the formation of ozone which is similarly produced by the combustion of petroleum oils.

Two names suffice to recall all that has been published on this subject: London, 1952, and Los Angeles.

I shall not dwell on the production of ethylene and its havoc to vegetation, nor even on the large quantity of oxides of carbon discharged by automobiles in our towns and congested areas. All this is well known.

I shall confine myself to drawing attention to the following facts:

(1) The problem of sulphurous gas could be solved by the compulsory de-sulphurization of petroleum. Actually, it is technically possible to reduce to 1 per thousand the sulphur content; but, in view of the time necessary to procure equipment and establish the process, I believe that it would be useful for, say, a period of two or three years, to fix this figure at 5 per thousand. The limit of sulphur content ought to be fixed internationally; but, for the time being, it should be on a national basis, in so far as the catalytic processes involved are economic to the petroleum companies. Besides, it is certain that, if the sulphur content has been considered as preventing the technical utilization of petroleum, this problem would have been solved years ago.

(2) Tetra-ethyl lead, with the actual processes of injection, has lost much of its value as an anti-detonator, and its addition could be avoided, since there is no reason why, eventually, petrol engines should not be replaced by heavy oil engines.

(3) As to internal combustion, two pieces of apparatus, one American and one French, by their attachment to the carburettor or to the intake, reduce the amount of fuel consumed, and proportion the delivery of fuel to the requirements of the engine: the apparatus completed by a catalyst associated with the exhaust (while it is still hot) is able to ensure total combustion and to eliminate from the exhaust all hydrocarbons, carbon monoxide, etc., whatever may be the nature of the fuel used. In addition, experience shows that in this respect the diesel engine is the most satisfactory.

(4) Since proprietors of motor vehicles, in order to increase the power or to use the apparatus to the maximum capacity, are tempted to modify the setting of the carburettor or its admission, I propose so to dispose the burners, injectors, pumps, etc., so that they can be sealed on delivery of the vehicles after having been adjusted. All subsequent modification of the apparatus would require approval. In addition, a regular periodic inspection of the apparatus would be imposed. Should the seals be broken, it would follow automatically that the vehicle would be impounded until it had been readjusted, and, in addition to the cost involved, a fine would be imposed on the owner.

(5) Standards of conduct would be required of all drivers with the penalty of cancellation of permits to drive in cases of repeated offences (engines emitting smoke, etc.). It would be necessary also to facilitate the movement of traffic in congested areas by augmenting the provision of one-way routes, reducing the number of shopping places, making the use of parking places obligatory, and eliminating from the centre of cities all unnecessary traffic.

Industries and large undertakings

The question of industrial and commercial enterprises is much more complex, and each forms the basis of an enquiry, having for its object:

(1) To define the nature of the pollution;
(2) To study the remedies most appropriate to the elimination of the cause of that pollution;
(3) To impose their application;
(4) To organize the control and supervision of the plant;
(5) To establish a code of penalties in case of infraction.

The question of dust proceeding from smoke can be considered as technically solved, the special apparatus, cyclones, catalysers, precipitators, thermal and electric, are able to reduce dust pollution by 95 per cent.

The gas and odours can also be neutralized or destroyed by recuperation, neutralization, or combustion. The technical equipment is extremely varied and it is here that technicians, chemists, engineers, hygienists, etc., will be able most usefully to investigate, among themselves, and with the direct collaboration of the technicians of the industries concerned.

The appliances, having in view the safeguarding of public hygiene, do not constitute a charge on the industry, as industrialists tend only too often to consider it. They permit either an economy of fuel (by recuperation and increase of output), a recovery of utilizable primary material, or the opening of a new calorific channel, where often the transformation into energy of another kind is not to be despised.

It is therefore a compulsory economy, permitting a lowering of the price of the product, at the same time protecting the health and comfort of the surrounding population.

Plants producing an assessment of toxic substances, in spite of all appropriate means to prevent it, should be removed from congested areas and the locality of their installation should be studied from the economic and meteorological point of view, in order to minimize the harmful consequences from their operation.

Private habitations

The problem of domestic fires remains the most thorny, and its solution cannot be readily accomplished, in view of the transformations necessary, both to the habits of the public and to the apparatus that they use. In fact, it is hardly by attacking the nature of the fuel used that we will obtain a substantial improvement, for there is also its method of use; often improper and practically uncontrollable. There is also the use of unsuitable heating appliances. In addition, the higher cost of electricity and gas (the use of the latter being, besides, not without risk of poisoning and explosion) is a considerable obstacle to their use in replacement of coal. The employment of atomic energy in reducing the cost of electricity is, perhaps, a possible solution of the problem. Meanwhile, another solution offers itself, which would remain available even if atomic energy became domesticated; district heating. The problem has been studied in many countries, notably in France and the United States. It is alleged that heat furnished by central heating stations could be delivered at a price lower than that of existing industrial practice. Moreover, in all cities the problems of disposing of refuse becomes more and more serious. There is but one solution: its consumption in appropriate destructors. These, besides operating with minimum atmospheric pollution, can be utilized to recover the heat produced, for the production of hot water, for heating dwelling houses, or even for industrial use, or when the season requires less heat for the production of electricity. It is true that this type of plant is not operated without cost, but calculations show that very often the cost of a ton of refuse incinerated is not much more than that of a ton transported and distributed at its destination. It is necessary in the latter case to take account (and often one neglects it) of the inconveniences resulting from the proliferation of rodents and insects and the great risks of the distribution of germs and illnesses that such transport entails, without counting the cost of transport over large distances and the cost of the land over which it is strewn, costs which yield no return.

Other Sources of Pollution

I have little to say about air pollution by radiation, but I cannot avoid drawing attention to the almost regular increase, with important peaks, of beta-radiation thrown into the atmosphere after each atomic test, wherever the scene of the experiment. It is necessary, in this matter, to consider the terrestrial atmosphere as a whole, and it is urgent that the responsible governments should frankly recognize the responsibilities they bear. It is equally important that the specialists should occupy themselves by finding methods that would make possible, with equally useful scientific results, ways of carrying out such tests on the smallest possible scale, taking all possible precautions in respect of safety and preventing the contamination of the atmosphere.

Another problem connected with air pollution is that of open or green spaces that should be planned with care in the built-up areas. Their areas should vary, according to the district and density of the population, from 35 to 60 per cent of the total area. Every opportunity for achieving this objective in old towns, by the demolition of obsolescent buildings, may be taken with profit. Green spaces are, in fact, the only means for overcoming the pollution of the air caused by human and animal life. They diminish the seriousness of noise, and bring about a reduction of pollutants that the methods noted in paragraphs I, II, and III allow to continue. It will be equally useful for the emergency hospital services that are maintained in the town—all other hospital services and, in particular, those for contagious diseases, will benefit by being disposed on the periphery, and isolated by barriers of verdure, both in the interests of the sick and of the citizens (by limiting the dispersal of germs of contagious disease and giving better rest for the sick).

Finally, it is considered to be indispensable that all these measures should be supported by an international convention and national legislation. Their application should be supervised by technical inspectors, guided in their work by a directing committee consisting of administrative and technical members, at least one medical man specializing in environmental hygiene, an engineer and a chemist. Such a committee would carry out its mission in collaboration with the World Health Organization. A group of this kind would be found at national and local levels, and the latter would enjoy relative independence, being better able to appreciate the correct solution for each individual problem. The national groups would coordinate the local groups, and would supervise areas outside the towns. Infractions would be dealt with by *proces-verbaux* or on reports made by the police, inspectors of local authorities, or by other legal procedure.

For pollution of an accidental, unforseen character, a period should be allowed for the application of remedies, but fines should be applied automatically where the character of the infraction is indisputably established. Their rate would be a function of the seriousness of the pollution. They should be increased for repeated offences. In serious cases, or where the cause is negligence of the users of the plant involved, all measures for safeguarding the public health, up to the closure of the establishment, should be applied.

These short observations summarize in a general fashion the measures that one would wish to see applied for the elimination of air pollution. The technical details cannot be developed here in a satisfactory manner without going into long descriptions of methods. Besides, these, because of constantly evolving techniques, can be further improved or replaced by less costly or more efficient methods. These are some of the lines that appear to me to constitute a logical basis for continuing discussion.

III. 26

EDUCATION AS AN AID TO INDUSTRIAL SMOKE ELIMINATION

SYDNEY N. DUGUID, B.Sc.Tech., F.R.S.H., F.Inst.F., J.P., Chairman of The City and Guilds of London Institute's Advisory Committee on Boiler House Practice, Great Britain.

SUMMARY: The paper describes the work done and organization in being in Great Britain for the training and cartification of boiler operators as a means of smoke prevention and fuel efficiency. Results for recent years are given and methods of training outlined. The training of the smoke inspectors of the local authorities is also described.

This short paper has been written with the object of informing the members of the Conference, and particularly our Overseas visitors, of some of the efforts being made in Great Britain to train the men called on to operate industrial fuel burning plant. The opinion is widely held that without appropriately trained men the desired standards of clean air and fuel efficiency cannot be attained.

It is also hoped that our Overseas visitors will, in the discussion, tell us how they tackle the problem in their countries so that we may learn from their experiences.

A fuel-burning plant may be well designed, and properly installed, but unless it is operated by trained men the results may be disappointing.

In Great Britain training is not compulsory; the men decide of their own free will whether to undergo it or not. Consequently the number of trained men available is few compared with the number of those who need the training. It is, however, pleasing to report that the number of men coming forward for instruction during the last few years has shown a substantial increase.

What has already been accomplished?

Classes for the training of men concerned with the running of industrial fuel-burning plant were established at several Technical Schools and Colleges in this country in the year 1912. It was felt, however, that to secure uniformity of instruction and universal acceptance of any certificates awarded, the training should be put on a national basis. In 1930 The City and Guilds of London Institute were approached and they set up an "Advisory Committee on Boiler House Practice."

This committee got to work and in the course of time compiled four training syllabuses at various levels with an examination at the end of each. These are known as (1) Boiler Operator's Certificate; (2) Boiler House Practice, Intermediate; (3) Boiler House Practice, Final Grade; (4) Combustion Engineering. The Institute does not train the men, but keeps the syllabuses up-to-date, sets the examination questions and conducts the examinations at suitable centres and awards certificates to those who pass. Detailed syllabuses can be obtained on application to the City and Guilds of London Institute, 76 Portland Place, London, W.1. A booklet dealing with " The Boiler Operator's Certificate " can be obtained free at the Conference.

The following tables give the results of these examinations for recent years:

Table I

Subject No. 75—The Boiler Operator's Certificate

Year	*Month*	*Number of Candidates*	*Pass*	*Fail*	*Per cent Pass*
1958	May and January (1959)	2,261	1,751	510	77·4
1957	May and December	2,129	1,770	359	83·1
1956	May and June	1,347	1,094	253	81·7
1955	December	93	72	21	77·7
1955	May	866	716	150	82·7
1954	December	47	38	9	81·9
1954	May	709	552	157	77·8
1953	December	19	13	6	68·4
1953	July	125	102	63	80·1

The examination for this certificate consists of a written paper of three hours' duration, usually held in the evening, and a Practical/Oral test conducted on the firing floor of the works where the candidate is employed. This examination is intended for the Stoker and the candidate must have been employed as such for at least 1,000 hours before he is eligible to sit for it.

The operator's enthusiasm for training is in marked contrast to the reluctance of those higher up the ladder to come forward, and in some boiler houses, an awkward situation has arisen because the stokers know more than their immediate bosses about this subject.

The rapid success of the examination could not have been achieved without the co-operation of the National Coal Board, Central Electricity Authority, and the National Industrial Fuel Efficiency Service and, later, the Minister of Health who expressed his desire to see all the Stokers in the hospital service properly trained.

Where can training be obtained?

Most technical schools and colleges in this country are willing to put on one or more of the courses under review providing a reasonable number of students can be persuaded to take them. The classes are usually held in the evening during the Winter Session. Many men seem to experience difficulty in attending evening classes, particularly when the premises are some distance away or possibly in another town. To meet the needs of such men a new method of training has been developed over the last few years which might be called the "Tutorial correspondence system." This system is mainly responsible for the rapid increase in the number of men taking the Boiler Operator's Certificate examination.

The students are entered as a group for a correspondence course and each man receives instruction by post. He does the necessary written homework, which is marked and returned to him by the school. Once every four weeks the group meets under a chairman for a whole day. The morning is spent clearing up any difficulties which the student may have encountered in the month's study. In the afternoon the class goes to the boiler house for practical instruction. The whole course lasts six to eight months.

Many educationalists do not look kindly upon correspondence courses, but the fact remains that this system has proved an outstanding success with boiler operators.

Table No. II

Subject No. 76—Boiler House Practice, Intermediate and Final

Grade	*Year*	*Number of candidates*	*1st Class Pass*	*2nd Class Pass*	*Fail*	*Per cent Pass*
Intermediate	1959	299	150	95	54	81·9
	1958	304	149	87	68	77·8
	1957	338	161	85	92	72·8
	1956	248	89	84	75	70·6
	1955	199	97	49	53	73·4
	1954	282	98	95	89	68·4
Final	1958	105	25	43	37	64·8
	1957	94	26	37	31	67·1
	1956	86	21	48	22	75·6
	1955	106	25	51	30	71·7
	1954	145	41	62	42	71·0

The Intermediate examination consists of a written paper of three hours duration. The Final examination consists of two written papers each of three hours duration. Anybody taking these examinations can, if they wish, also take the Practical/Oral Test set for the Boiler Operator's Certificate, and if successful their Intermediate or Final Certificate would be endorsed with this fact.

Table III

Subject No. 77—Combustion Engineering

Year	*Number of candidates*	*1st Class Pass*	*2nd Class Pass*	*Fail*	*Per cent Pass*
1959	16	Not yet known	—	—	—
1958	7	4	1	2	71·4
1957	8	2	3	3	62·5
1956	6	1	5	0	100
1955	16	1	9	6	62·5
1954	8	2	4	2	75

The examination in Conbustion Engineering consists of two written papers, each of four hours' duration.

Paper 1. Fuels, Combustion, Heat Transfer.
Paper 2. Steam Generation, Flow of fluids, Instrumentation, etc.

Paper 1 may include questions involving the ancillary subjects Inorganic Chemistry and General Physics.

Training of the Smoke Inspector

The Beaver Report recommended that "Local authorities should employ adequate smoke-control staffs with the proper training and technical qualifications".

Since 1914 The Royal Society of Health, London S.W.1, has conducted examinations for Smoke Inspectors and issued a Diploma to those who passed.

The Society has laid down the Regulations and Syllabus governing the examination, which is open to all over 21 years who can produce satisfactory evidence of having completed an "approved" course of instruction. The City and Guilds of London Institute Intermediate course in boiler house practice is an "approved" course.

The results of the examinations held during the last seven years are as follows:

Table IV

Smoke Inspector's Examination, Royal Society of Health

Year	*Number of candidates*	*Pass*	*Fail*	*Per cent Passes*
1958	135	71	64	52·6
1957	132	68	64	51·5
1956	91	54	37	59·3
1955	70	34	36	48·6
1954	68	30	38	44·1
1953	52	24	28	46·1
1952	56	30	26	53·6

Since the inception of this examination in 1914, the number of Smoke Inspectors' Diplomas awarded is 1,121.

The influence of the Clean Air Act, 1956 is, no doubt, responsible for the gratifying increase in the number of candidates sitting for this examination in the last three years.

Conclusion

The rate at which the men are coming forward to be trained under these voluntary schemes is not adequate to meet present requirements and some kind of compulsion is necessary.

The National Society for Clean Air, and many engineers outside the Society have long held the view that only trained and certificated men should be allowed to operate fuel burning furnaces, but no one at the necessary high level has thought fit to take action.

The Technical Committee of the Society is at present drafting a Bill, which it hopes may be eventually presented in Parliament, that would make it an offence to employ any person to be in charge of the firing or other direct operation of any furnace unless he possessed an appropriate certificate.

Many deplore the fact that this matter was not dealt with in the Clean Air Act, 1956, but perhaps some enterprising M.P. may sponsor the Society's Bill and thus repair the omission.

III. 27

REMOVAL OF DUST FROM BROWN FUMES IN OXYGEN-BLOWING STEELWORKS

Dr.-Ing. KURT GUTHMANN, Verein Deutscher Eisenhüttenleute, Düsseldorf, Federal Republic of Germany.

SUMMARY: The problem of removing dust from the brown fumes arising in the LD-(Linz-Donawitz) oxygen steel making process may be regarded as solved. In some cases a reasonable use of waste heat and precipitated dust may even make gas cleaning an economic proposition. Electrostatic precipitators were found to give the best results and the utilization of waste heat is considered a prerequisite for any economic method of dust removal. Examples are given of several arrangements of plant and the operational results therefrom.

Fortunately, after years of development work, the difficult task of *removing dust from the brown fumes arising in the LD-(Linz-Donawitz) oxygen steel making process* may be regarded as solved. In some cases a reasonable use of waste heat and precipitated dust may even make gas cleaning an economic proposition[1]. the extremely fine spherical dust particles of the brown fumes, of which 80 per cent is smaller than 0·8 micron, the remaining particles ranging from 0·1 to 0·3 micron with a large percentage of 50 millimicrons, and waste gas temperatures of up to 1,800°C, are the main difficulties encountered in dust removal.

Electrostatic Precipitators

At Donawitz (Austria) more than 500 tests were made on eight different gas cleaning installations, and of the dry cleaning systems the electrostatic precipitators were found to give the best results. The *utilization of waste heat* is considered a pre-requisite for any economic method of dust removal involving cooling of the brown fumes to 300 or 350°C, the waste heat being recirculated, say, in a forced circulation boiler with evaporation drum (Lamont boiler of 58 atü). An average *steam generation* of some 300 kg per ton of steel produced may be expected.

The *total cost* of the dust removal plant at Donawitz used for a 30 ton LD-crucible and including the steam generation equipment was some 5·7 million DM; this was a first installation, and assuming a yearly depreciation of 10 per cent as well as steam and dust credits, a subsequent production of 400,000 tons per year of LD steel would yield a gain of some 1·65 DM per ton of steel.

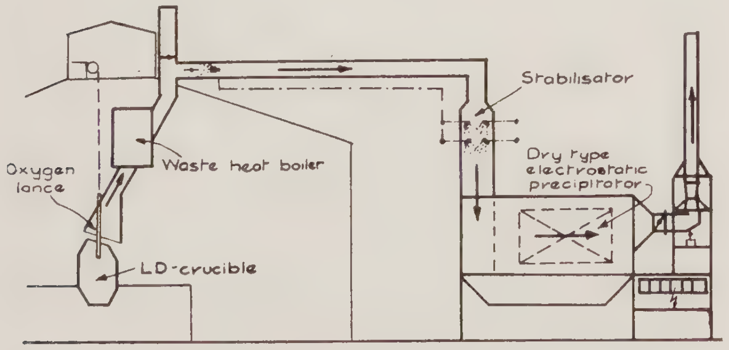

Fig. 1. Donawitz plant: waste heat boiler and dry type electrostatic precipitator

Figure 1 shows the Donawitz plant consisting of waste heat boiler and dry type electrostatic precipitator. Enough water is injected automatically into the evaporation cooler (stabilizer) to maintain the electrostatic precipitator at a service temperature of some 150°C. All the injected water is evaporated. The dust trapped in the electrostatic precipitator—some 12 tons/24 hr—is dry, consequently there is no need for water and effluent preparation or clarification. The dust is filled into paper bags and re-used in the LD-crucible before charging the liquid pig iron.

Operational results

LD-crucible	33 tons of pig iron
Blowing time	22 minutes
Waste gases	50,000 Nm^3/h (0°C)
Dust production	350 kg/heat 1·09 per cent referred to ton of steel produced
Dust loading at precipitator inlet	11·7 g/m^3
Dust loading at stack outlet	140 mg/m^3
Removal efficiency ...	99·88 per cent
Power consumption of electrostatic precipitator ...	0·23 kWh/t of steel
Power Consumption of total plant including blowers ...	0·62 kWh/t of steel
Water consumption ...	1·5 m^3/heat

For a 40-ton crucible with waste heat boiler the total cost of dust removal is, at present, 0·65 to 0·50 DM per ton of steel.

In the *LD-gas cleaning plant of Gusstahlwerk Witten/Ruhr* (figure 2) the brown fumes pass, after cooling down to some 250°C, through a mechanical wet type cyclone and then, for secondary cleaning, through a wet type of electrostatic precipitator. From the waste heat boiler, which is equipped with additional automatic oil firing, 20 tons of high-pressure steam can be drawn off continuously. After several years of experiences it appears that this boiler is no less robust than any other modern high-pressure boiler.

At *Linz-Donau* (VOEST), (Figure 3), the waste gases are first passed through turbulence tubes with water injection, then through a saturation chamber (gas velocity 2 m/s) into a tubular wet electrostatic precipitator cleaning 13,300 Nm^3 of gas per heat containing 350 kg of dust, or an inlet dust loading of 26·4 g/Nm^3 to an outlet dust loading of 86 mg/Nm^3. This represents a removal efficiency of 99·7 per cent and a dust emission of 1·1 kg/heat, the total pressure drop being 470 mm water column. The Witten/Ruhr and the Japanese plants operate on a similar scale.

In a more advanced stage, good results were obtained by " differential " wetting of the gas in a filter cell; after reaching a relative saturation zone 50 to 90 mg/Nm^3 of dust were eliminated by a comparatively small filter unit, the pressure drop being 700 to 750 mm water column and the fresh water supply some 2 m^3/heat.

Pease-Anthony Venturi scrubbers

At the *Yjmuiden oxygen steelworks*, the largest existing works, with two 70 ton LD-crucibles of 25 minutes

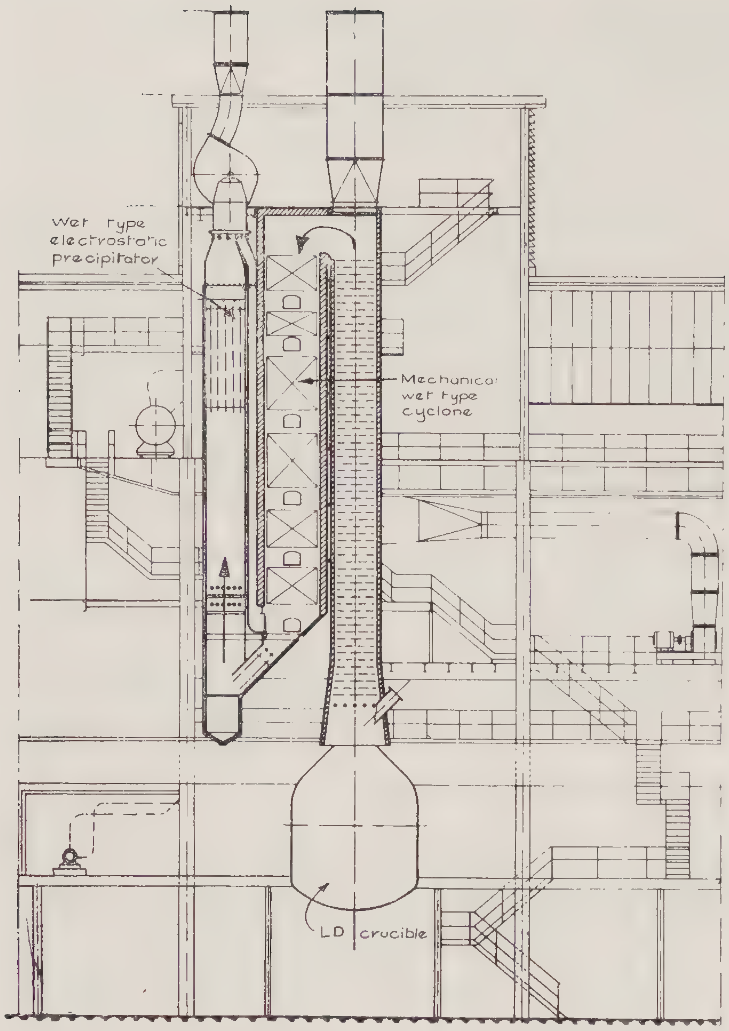
Wet type electrostatic precipitator
Mechanical wet type cyclone
LD crucible

Fig. 2. Gas cleaning plant at Gusstahlwerk Witten/Ruhr (waste heat boiler, wet type cyclone, wet type electrostatic precipitator).

blowing time each, 126.000 Nm³ or 300,000 m³ respectively of waste gas are produced from which, because of the adjacent tulip and narcissus fields, the greater part of the dust is removed in a Pease-Anthony Venturi scrubber. Water consumption is some 25 m³/heat or 350 kg/ton of pig iron charged, while the clean gas contains some 110 mg/m³ of dust.

A special dust removal system according to the Pease-Anthony Venturi method was developed for the oxygen steelworks of the *Bochumer Verein.* The waste gas production is reduced to about half its original volume by indirect hot cooling of the combustion chamber, with the crucible stack working as a radiation boiler providing at the same time for indirect heat removal and steam generation. The gas cleaning plant is situated between the steelworks building and the converters.

Using a “ full-cooling ” (convection) boiler and indirect heat removal down to 300°C, the waste gas volume can be reduced to 390 m³/ton as compared with 590 m³/ton when cooling partially. The water consumption is only 50 kg/ton of pig iron charged, the current power consumption for hot cooling, the entire water economy and iron oxide recovery is some 5 kWh per ton of pig iron. However, in this instance the capital cost had been extremely low. With indirect cooling of the waste gas (using full-cooling convection boilers) a power consumption of 1·8 kW/ton of pig iron is reported.

Regarding *sludge water preparation and iron oxide recovery*, the fresh water circuit at Yjmuiden reportedly permits the recovery of 0·8 per cent as referred to Fe-metal. Some 10 per cent by weight of CaO is added to the sludge filter cake so that 800 to 900 tons per month of a material highly suitable for treatment in the sinter plant is obtained.

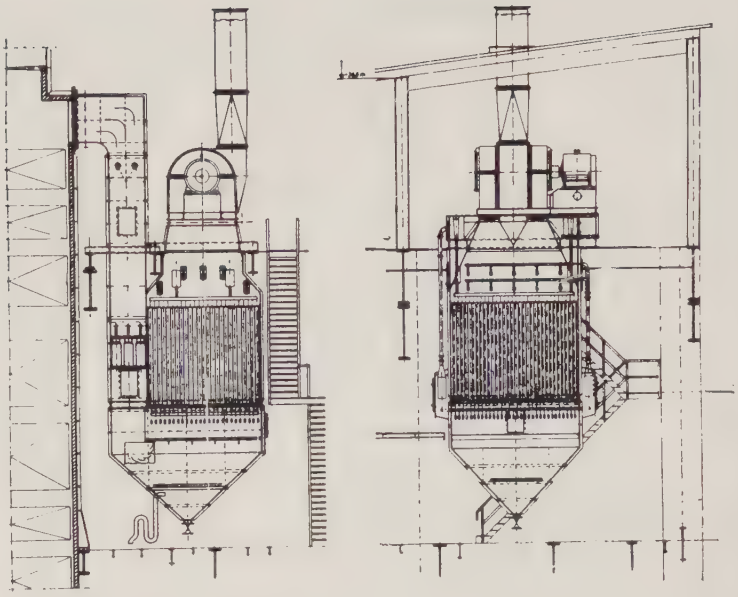

Fig. 3. Gas cleaning plant at Vöest, Linz/Donou (wet type turbulence tubes, wet electrostatic precipitator).

The new *LD-steelworks of the Bochumer Verein* has two 35-ton crucibles (in addition to a 70-ton arc furnace) for which an 8·4 m wide and 39 m high induced-draft “ smoke bay ” has been built. This plant has been modelled on the two North American works of Dofasco at Hamilton on Lake Ontario and McLough at Trenton near Detroit on Lake Erie. Dofasco uses Pease-Anthony Venturi scrubbers, McLough disintegrators, both consuming large quantities of water. The brown effluents, unclarified in the first case, clarified in the latter case, are discharged to the lakes. In the recirculation system at Bochum, which is satisfactory in every respect as neither surface water nor ground water is polluted, a Pease-Anthony Venturi scrubber is incorporated consisting of saturator, venturi tube and separator.

The waste gases having a temperature of some 1,800°C, are exhausted with an underpressure of 1,300 mm water column, they are first pressed through the Wagner-Biro waste heat boiler (cooling through indirect condensation) then, at some 80°C, through the wet cleaning plant. At present the steam obtained (55 atü) cannot be utilized as it is not generated continuously, and none of the works' divisions uses steam. Therefore, the steam is condensed in a special installation, the condensate being recirculated to the waste heat boiler.

The cleaned waste gases leave the stack at a temperature of approximately 70°C in the shape of a smoke plume whose light colour is due to a residual dust loading of less than 150 mg/m³. The water consumption for dust removal from the brown fumes is stated to be 0·3 m³/ton of raw steel.

Regarding particle size, only some 10 per cent is above 0·96 millimicron while 90 per cent is in the range from 0·001 millimicron. The primary dust consists almost exclusively of particles entrained from the liquid slags or additions, this dust is intercepted in the saturator virtually up to a size of 60 microns. Some 15 to 20 per cent of the total dust production is removed in the *saturator*, 85 to 80 per cent in the *Venturi scrubber* (mostly below 60 microns).

In the Humboldt-Deutz preparation plant the sludge water, to which some lime milk has been added, is clarified in thickeners, the thickened sludge is drawn off and filtered in cell-less revolving bag filters. The filter cake still contains some 30 per cent of moisture, while the dried cake contains some 50 per cent of iron. From a 35-ton heat some 800 kg of thickened sludge are obtained representing 560 kg of dried material with 280 kg of Fe; that is 8 per cent of the charge.

The sludge water entering the thickener contains 6 to 10 kg of solids per m^3 of water, at the outlet it contains some 300 to 800 g/m^3. The average solid concentration of the filtrate of the bag filters is 50 g/m^3.

With only a small volume of steam being used and including the service of capital and credits (iron from the sludge, water preparation) the cost of dust removal (steam generation and condensation, wet cleaning, clarification) is about 3·05 DM/ton, viz. 1·94 DM for the boiler plant including condensation plus 1·11 DM/ton for dust removal. The *capital cost* for boiler plus condensation plus wet cleaning plus clarification was some 3·8 million DM.

III. 28

TECHNICAL REMOVAL OF DUST AS DEALT WITH BY THE EUROPEAN COAL AND STEEL COMMUNITY HIGH AUTHORITY, LUXEMBURG.

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SUMMARY: In 1958 the High Authority of the Coal and Steel community, in agreement with the Special Ministers' council, approved considerable grants in aid to assist in carrying out the four-year study in the field of dust removal in collieries, iron ore mines and metallurgical industries. This paper is an outline of the programme for this four-year study, under the following headings: technical removal of dust in mines with particular attention to combating silicosis, and technical removal of dust in the iron and steel industry, which latter is divided into applied and basic research.

In 1958, the High Authority, in agreement with the "Special Ministers' Council", approved of considerable grants-in-aid to assist in carrying out a four-year study in the field of dust removal in collieries, iron ore mines and metallurgical industries.

To serve as a guide in the research, programmes were outlined for the following fields:

Technical removal of dust in mines with particular attention to combating silicosis, covering the following items:

Drafting of new methods, and development of existing ones, of measuring dust in mines:

(a) direct measurement of dust accumulation;
(b) methods of sampling dust;
(c) methods of testing the intercepted dust.

Testing of mine dust:

(a) quality of the dust (e.g. mineral qualities);
(b) properties of the dust (e.g. electric loading);
(c) behaviour of the dust underground (e.g. influence of turbulence, moisture, sedimentation).

Drafting of new methods, and development of existing ones of removing dust in mines:

(a) pulsed infusion method;
(b) pneumatic packing and caving system;
(c) shotfiring;
(d) dust suppression in various extraction methods;
(e) elimination of deposited dust;
(f) dedusting of ventilation air, especially of the intake-air;
(g) dust suppression in plants with particularly heavy dust production (e.g. skips, crushing units, transfer and loading points);
(h) suppression of draining and boring dusts, particularly in armoured supports.

Protection of mining personnel *against dust:*

Control of work distribution, study of dust loading and occupation.

Technical removal of dust in the iron and steel industry

Applied Research

Drafting of new methods, and development of existing ones, for

1. (a) combating of dust and silicosis to protect furnace bricklayers, ladle makers and other workers dealing with silica refractories;
   (b) combating of dust and silicosis to protect workers engaged in pattern-making, core-making, shakeout, castings cleaning and sandblasting operations.
2. Removal of dust and fumes incidental to *oxygen steel making processes*, particularly
   (a) in converters or LD-crucibles of steelworks using pure oxygen or oxygen enriched blast.
   An industrial scale pilot plant is in operation at the basic Bessemer works of Mannesmann-Huttenwerke Huckingen (Duisburg) consisting of waste heat boiler (steam pressure of 65 atu, 475°C) and Lurgi dry type electrostatic precipitators of some 280,000 Nm3 (0°C) capacity per hr.
   (b) in electric arc furnaces;
   (c) in oxygen scarfing of raw steel ingots.
3. Protection against dust and fumes arising in steel-melting furnaces converters, LD-crucibles, cold and hot blast cupolas, heating furnaces, drying stoves, ladle heating, etc.
4. Removal of dust arising in blast furnace *charging* operations including crushing and screening of iron ores and additions; in *sintering* fine ores of every description including storing and handling of ores, additions and agglomerates.

Basic Research

Work undertaken in connection with:

1. homogeneization of dust measuring methods in the metallurgical industries with a view to standardizing:
   (a) reference factors (e.g. measured dust accumulation referred to ton of steel produced or to m3 of gas/sec; measuring or weighing of dust particles, etc.);
   (b) measuring instruments and measuring methods.
2. Determination of dust accumulation at various working places in the metallurgical industries, especially:
   (a) the type of dust (chemical and mineralogical composition, grain structure, etc.);
   (b) the amount of dust;
   (c) the number of operators occupied at these working places;
   (d) the danger of dusts of various kinds.

GAS IN INDUSTRY

R. F. HAYMAN, Industrial Gas Officer, Gas Council, Great Britain

SUMMARY: The paper reviews the many uses of gas for industrial purposes in Great Britain, with reference to increased technical efficiency and convenience as well as to the prevention of smoke and reduction of sulphur oxide emission. Examples are given.

The Gas Industry in Great Britain is fortunate in that gas is a fuel which is not only almost perfectly adapted to the needs of modern industrial processes but can also be guaranteed to burn smokelessly and with a very small, usually negligible, emission of sulphur to the atmosphere.

The Industry sells not only a fuel but a service aimed at making goods at the lowest possible price of fuel per unit of production. This does not mean that the cheapest fuel must always be used. Modern requirements often demand high output or increased production in existing space or with existing plant, and in increasingly cleaner conditions. The cheapest steels, including mild steel, are now required to be processed in a bright and clean state to avoid costly cleaning and refurbishing processes. It is in operations made up of inter-dependent processes, in which heat treatment is but one, that the Gas Industry plays a major part by putting a reliable and clean heat service into a continuous production line. Machine tools costing many hundreds of pounds can be heat treated by gas for a few shillings, but can be ruined by the casual application of the wrong heat treatment and atmosphere conditions.

The need for greater control over operations has resulted in spectacular changes in techniques. Up to the present time in the Potteries some 330 kilns have been converted or designed for gas heating. In this district alone it has meant a saving of approximately half a million tons of coal per annum which used to be burned in a raw state. Great basic industries like pottery and ceramics have often had to change their methods to suit consumers' requirements, particularly when so much is dependent on the export trade. For this reason, although large scale production continues, there has been a call for smaller plant to deal with special batches of ware and this has necessitated new designs of kiln, such as the multi-passage type. These kilns are capable of large throughputs but with great flexibility in order to cope with demands for specially fired ware, and many of these gas fired units are now being put into satisfactory operation.

The use of bituminous coal for heating ceramics drying rooms is no longer admissible in some areas which already come under the influence of the Clean Air Act, and it is certain that gas can do valuable service in this essential field in the years to come.

In iron and steel foundries the use of raw fuel for some processes is no longer permissible. The Iron and Steel Foundry Regulations, 1953, forbid the use of open coal, coke or wood fires for space heating, drying or heating ladles or mould drying. Another clause insists that mould stoves, core stoves and annealing furnaces should not cause offensive fumes to enter the workroom.

Gas has taken a major role in providing improved or new heating techniques for the drying and re-heating of ladles, and the drying of cores and moulds The older systems of mould drying using heavy solid fuel fired braziers were inefficient in operation and created an unhealthy and sometimes dangeroou atmosphere not only within the vicinity of the mould but in the shop.

The production of smoke is primarily a problem of incomplete combustion. By installing gas fired equipment it becomes possible not only to eliminate smoke and atmospheric pollution but to ensure closer control over a process. For example, the use of gas has reduced ladle heating times by 30 per cent for small ladles and 65 per cent for large ladles of 20 tons or more in weight. Again, by re-designing large mould drying ovens the drying cycle time has been reduced by two thirds on half the cost of the original solid fuel, with no production of smoke.

The conversion of coal fired plants to gas, although not so satisfactory as the installation of equipment designed for the process, often has to be undertaken because of the need to eliminate smoke whilst using as much of the existing plant as possible. This can sometimes show overall running costs lower with gas than with raw fuel even where gas is more than twice the price per therm. A consumer whose chimney constituted a smoke nuisance was able to continue in production by the redesign of his process to use gas instead of coal for heating. Improved operation conditions reduced the fuel cost by 40 per cent with the attendant advantages of complete absence of smoke, no labour for stoking, greater cleanliness and simple and precise control. In another case the smoke nuisance in burning off paint from wire gauzes in a solid fuel grate was eliminated by passing the gauzes through gas burners emitting high velocity jets of hot gases.

Some industries have to handle dirty or noxious products and burning is often the most practical way of disposal. The elimination of waste rubber is a typical problem and gas fired incinerators are able to eliminate smoke and subsequent complaints of smell. It is not only individual processes which must be considered, since in many congested areas the presence of smoke or smell may embarrass a neighbouring factory and prejudice its prosperity, particularly if it is making food products. The advantages of smokeless fuels thus cover a wide field, and the benefits of smoke prevention from a single process can often be felt over a large area.

The use of gas in these and many other examples means that not only is coal being saved and atmospheric pollution made less severe, but the cost of production of goods is cheaper.

A clean flue or the absence of smoke in a stack does not always ensure clean air. Sulphur is a constituent of many fuels, but the Gas Industry is making a substantial contribution to clean air in that the sulphur content of town gas is small (an average of 30 grains per therm) and it is the intention to bring this value to well under 15 grains per therm before long. The figure for coal equivalently used is 850 grains, thirty times as large as for gas. This means that in the potteries half a million tons of raw coal now annually saved by using gas has eliminated the emission of some 4,000 tons of sulphur a year, equivalent to more than one hundred million cubic feet of sulphur dioxide.

The need for increased working amenities has resulted in some open sites being converted to covered and closed buildings. Once a structure has been covered it becomes subject to the Factories Act and heating may be required. Large buildings with high roofs can become comfortable at reasonable cost if high level radiant heating is used. Gas radiant units automatically lit and controlled from ground level are being increasingly used to provide cleaner and more pleasant working conditions without any possibility of smoke emission. In one works alone about 480 heaters are being installed with a comprehensive thermostatic and clock control system to maintain a suitable level of comfort.

The current annual rate of sales of gas to industry is some 800 million therms. The resources of the research and development departments of the Gas Council and the Area Boards are at the disposal of consumers. Gas is used for thousands of processes and by fostering new methods of smokeless heat treatment for the more difficult problems for example those arising from incineration, the Gas Industry ensures that the growing sale of gas to industry is a continuing contribution to cleaner air.

THE PROBLEM OF AIR POLLUTION BY DIESEL ROAD VEHICLES

J. W. JACQUEST, Diesel Development Officer, Armstrong Siddeley Motors, Ltd., Great Britain

SUMMARY: A very great deal of the increasing nuisance from diesel smoke is the result of poor or non-existent maintenance. Fuel injection equipment is complicated and requires regular maintenance; compression should also be checked frequently. Operators should realize that smoking engines waste fuel. Improved techniques in fuel injection and maintenance would reduce emissions to an acceptable level.

Diesel smoke is a problem which, in these last few years, has had more than its share of publicity. Many experts have ventilated their theories in scores of excellent papers, via the press and technical institutes, but as each year passes, more and more diesel-engined transports appear on our roads, until this modern menace has reached such appalling proportions that it is now the prime target of public resentment, and quite rightly so. No engine ever left the manufacturer with an exhaust condition that is so obviously anti-social.

Every conceivable excuse has been made by people in transport, blaming the fuel, but it must be remembered that the manufacturer rates his engines with exactly the same fuel as that used in transport. In addition, many thousands of hours of development work on combustion chamber design is carried out, and the closest co-operation is maintained with the manufacturers of fuel injection equipment. This equipment is manufactured to the finest limits to allow for the accurate metering of the tiny quantities of fuel introduced into the cylinder during each cycle. Surely it cannot be expected that precision and complex fuel systems can remain at this high standard of efficiency for indefinite periods.

Maintenance periods are either too infrequent, very badly carried out, or an absolute necessity, judging by 90 per cent of our road vehicles. It is not sufficient to have the nozzles checked and cleaned every 10,000 miles, or when the engine has to be stripped for major overhaul. How many operators check the engine compression at frequent intervals? After all, the diesel is a compression ignition engine, and any loss in volumetric efficiency due to leaking valves or piston blow-by will produce excessive smoke and high fuel consumption. Restricted air cleaners, exhaust systems, faulty cylinder gaskets, excessive valve clearances, incorrect spill timing, all contribute to an increase in smoke level, and very quickly deteriorate during service. These are all maintenance jobs, but very few operators outside the more efficient transport concerns as yet feel they can afford the equipment and the trained staff to carry out this type of work.

More frequent and better maintenance, with trained staff using the latest equipment, must be introduced if a serious effort is to be made to reduce and eventually eliminate the injurious clouds of diesel smoke that abound in town and country. The control of diesel smoke is the responsibility of the users, and it would be a great contribution to the Clean Air Campaign, particularly if it could be achieved voluntarily. We cannot wait for the fuel chemists to create fuel additives or new fuels of greater volatility, or for someone to perfect an official afterburner which could prove to be another expensive accessory, subject to the same neglect as the existing equipment. Maintenance should be rationalized, not further complicated.

It is, of course, extremely difficult in a short paper to deal with the complexities of this serious problem. Many prominent and well-informed authorities have expounded their theories on the grave dangers of exhaust smoke, and much research work is still being carried out to find a final solution. However, while the boffins ponder, the urgent problem is to clean up our roads and cities. The existing conditions just cannot be allowed to continue.

The general use of improved techniques in fuel injection and engine maintenance would eliminate the worst conditions and improve performance all round. If all diesel operators could be brought to realize that a smoking engine is operating inefficiently, with resulting loss of power and waste of fuel, a rapid change for the better would come about. In fact, most of the vehicles smoke associated with diesel engines could be avoided by appropriate action on the part of the fleet operators. It is sincerely hoped that if those responsible for the running and maintenance of fleets would in the future ensure that fuel injection equipment and engines functioned as the manufacturers intended them to do, diesel smoke could be controlled at a level acceptable to the most fastidious authorities.

III. 31

ENVIRONMENTAL ARSENIC CONTAMINATION AND CONTROL IN SMELTING OPERATIONS

KINGSLEY KAY, M.A., Ph.D., Department of National Health and Welfare, Ottawa, Canada

SUMMARY: Arsenic poisoning has in the past only occurred in areas remote from population centres and has therefore not affected human beings. Human poisoning has recently occurred in a populated area of Canada adjacent to two smelters engaged in the extraction of gold. After poisoning of cattle and humans, a continuous survey was started. A feature of the survey was the urinalysis carried out on local school children. The methods adopted to collect and store the effluent are described. The study shows that even in remote areas population concentrations develop when processes are successful. Operations must be planned with protective measures and uncontrolled stack discharge is not desirable.

As early as 1907, Harkins and Swain reported on assessment of environmental contamination by arsenic from smelting operations. These authors discussed the effect of high stacks and condensing chambers in reducing local contamination. A study of arsenic in vegetation was described by Swain and Harkins in 1908. Concurrently Haywood (1907) and Harkins and Swain (1908) considered injury to vegetation and chronic arsenical poisoning of herbivorous animals. These latter authors reported on the occurrence of fatal arsenic poisoning among cattle grazing in areas close to certain smelters in the Western United States. In these incidents as well as in others which have occurred in the years that followed, poisoning was confined to cattle and wildlife, as the operations concerned were in remote areas not adjacent to centres of population. Recently human poisoning has occurred in a populated area of Canada adjacent to smelting operations where arsenic-bearing roaster fumes were discharged to the atmosphere. Each of these incidents has contributed to knowledge of methods for controlling discharge of such effluents but the Canadian incident has special interest because it involved a populated centre. The changes in environmental levels of arsenic were assessed in relation to changes in roasting process and collection equipment. Furthermore, assessment of urinary levels in children of the area was also carried out, this constituting possibly the first large-scale biological correlation in this field.

In the Canadian situation two roasters, 3 miles apart with a 3,000-person townsite in between, handle locally-mined arsenopyrite ore to drive off arsenic and release the gold content. This process was begun on a production scale several years ago and the arsenic trioxide fume was discharged to the atmosphere. The development of these mines was successful and though the area was remote it did not remain unpopulated for long. Within a few years arsenic pollution had become widespread and occasioned the death of a herd of cattle and some cases of illness to humans. At this stage officers of the Occupational Health Laboratory, Department of National Health were called in to assess the health hazard of the widespread arsenic pollution.

A comprehensive survey was set in motion under which arsenic levels in air, water and vegetation were followed. Assistance from the two mines was obtained in the sampling program. All analyses were by the Gutzeit method.

About a year after production started Mine No. 1 installed an experimental scrubber which collected the fume successfully but produced an arsenic bearing sludge. When the survey began Mine No. 2 was encouraged to install a collection device and Cottrell precipitation was chosen.

The problem of disposing of the collected arsenic was serious. In the mine employing a scrubber, 16 tons of arsenic-bearing sludge were produced per day. This was discharged to a nearby lake and soon raised the level of arsenic in the lake to as high as 40 ppm. Furthermore the contamination began spreading to adjoining lakes used as an occasional source of drinking water. To correct this situation a storage basin was constructed. At Mine No. 2 employing Cottrell collection, chambers were tunnelled out of the permafrost zone between 20 and 100 feet underground. The dry trioxide was pumped into the chambers and sealed off. To date no definite evidence of leakage of arsenic either from the storage basin or the permafrost chambers has been found.

The impinger-scrubber used at Mine No. 1 has continued to collect at efficiencies above 90 per cent. Unfortunately, however, the Cottrell collection efficiency deteriorated in a few years after installation presumably due to increased loading and a change in the composition of the roaster fume as a result of the addition of a vertical type roaster. An additional Cottrell unit was added bringing collection efficiency from 40 to 70 per cent. This was followed by a striking reduction in fall pan collections. Further measures were recommended to raise collection efficiency and a bag collector was chosen. The effect of this measure cannot yet be assessed.

Environmental Sampling Data

Settled Arsenic

At Mine No. 2 collecting by Cottrell, there was a striking reduction in airborne arsenic effluent measured as arsenic settling in fall pans, after the installation of the second Cottrell early in 1955. This is shown in Figure 1. The average figures based on 15 sampling locations within a radius of one mile from the discharge stack have remained low, though further reduction in levels are still sought by the consultants in the interests of reducing environmental contamination to a minimum.

The fall pan data from the smaller mine collecting by impinger-scrubber represent averages of 6 points within a one-mile radius. This is shown in Figure 2. It is evident that levels reflected technical changes related to arsenic discharge, particularly at Mine No. 2 which by virtue of its large tonnage discharge had a substantial effect on settled arsenic in the area of Mine No. 1, a distance of three miles.

Asenic in Water

The levels of arsenic in water are shown in Figures 3 to 8. Tap water was drawn from one large body adjacent to the area. The data show first that spring and early summer water from three tap sources contained arsenic in excess of the safe 8-hour per day continuous intake standard of the United States Public Health Service. This is, of course, due to the

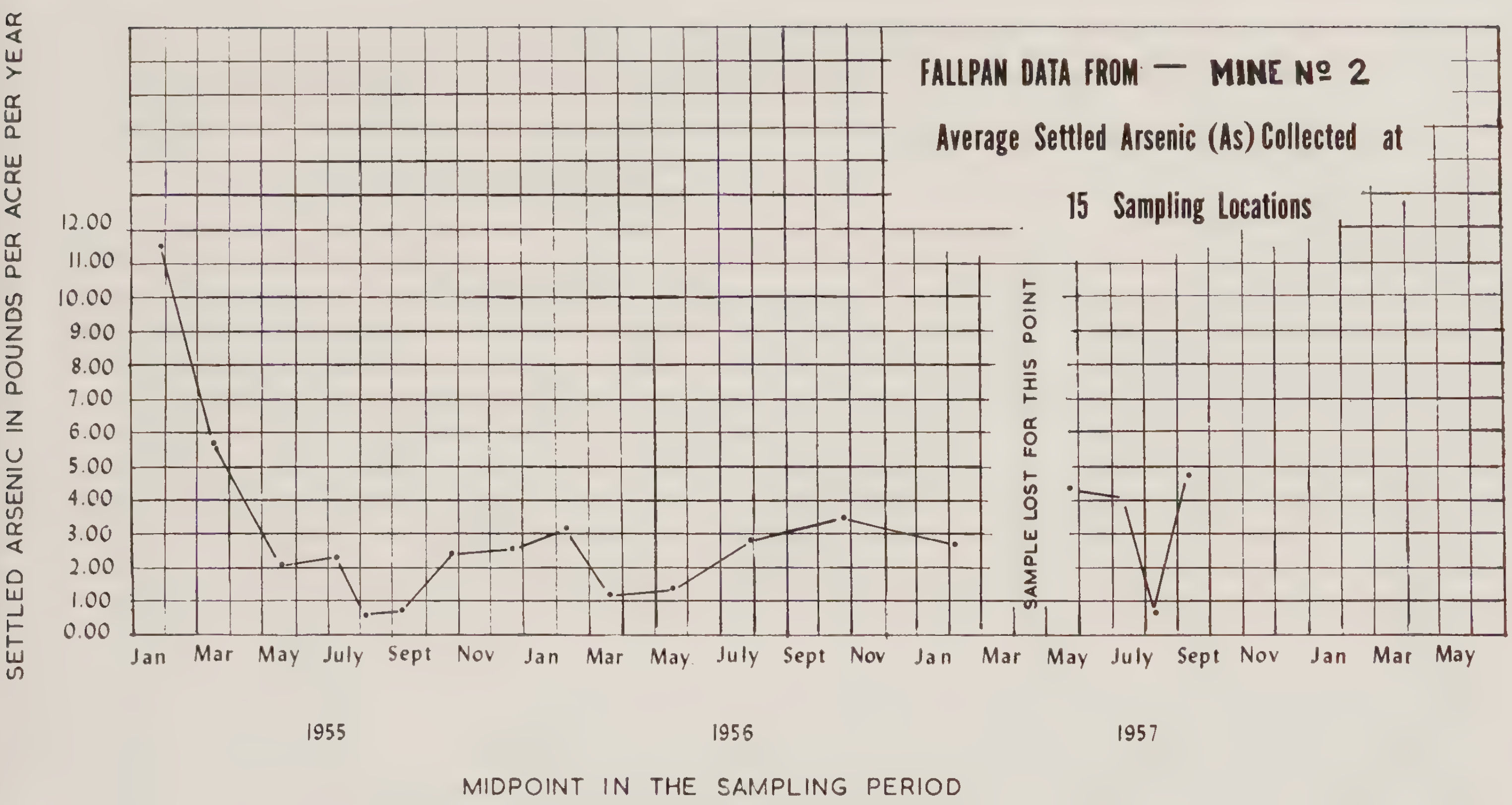

Fig. 1

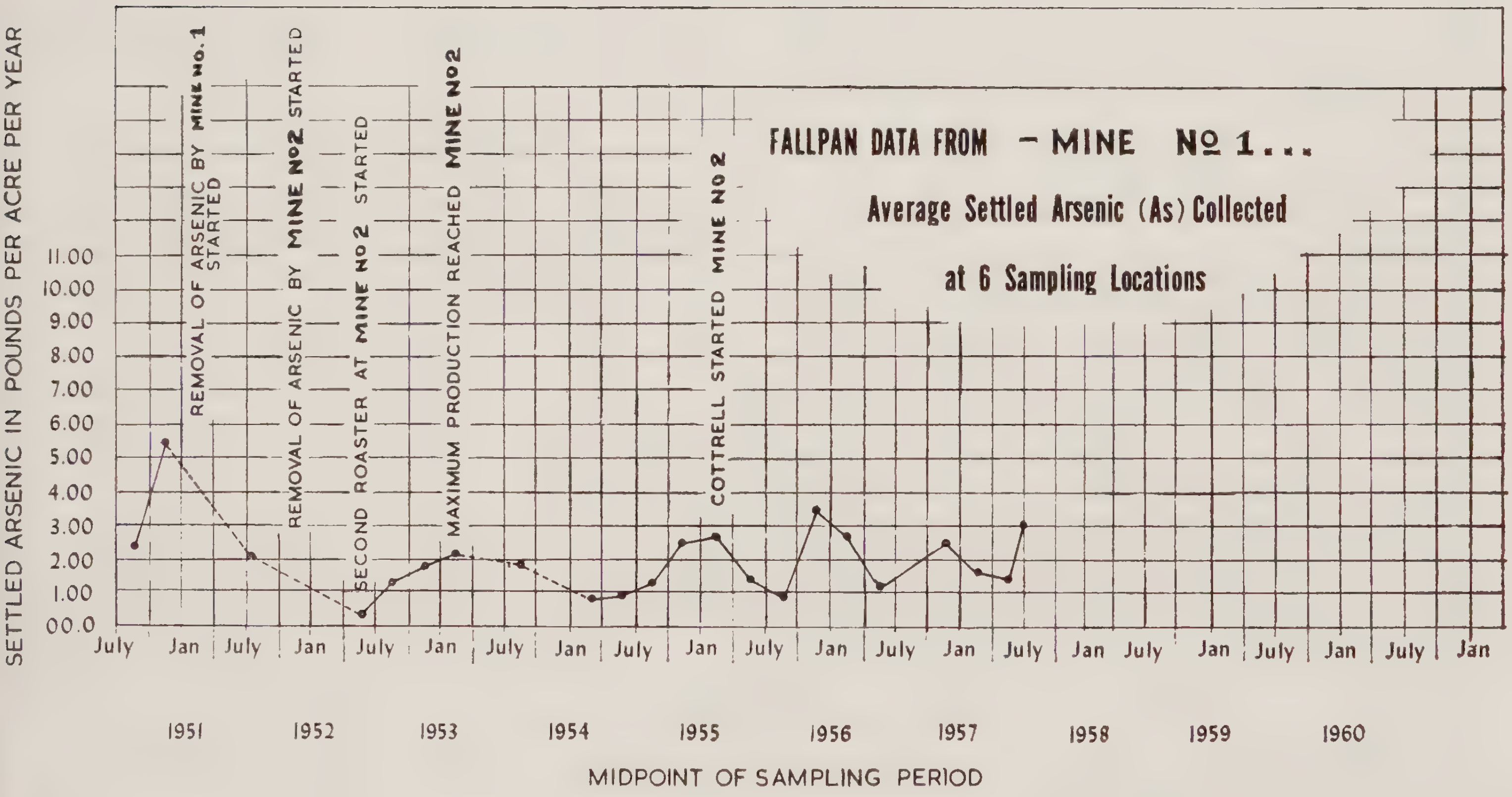

Fig. 2

release of arsenic collected on snow during the winter. Higher levels for the tap water from Mine No. 2 with the Cottrell installation seem to reflect the lower collection efficiency and higher arsenic output. It is to be noted, however, that excessive levels of arsenic were of limited duration.

Figure 8 shows that arsenic in samples from small lakes in each area has been gradually increasing. These were not organized sources of water supply Most of these lakes have no outlet being craters in the rock formation of the area. Presumably they are collectors of arsenic which is being washed into them by rain and at spring melting year by year. The higher values for Mine No. 1 result from the influence of water-discharged arsenic sludge.

Arsenic on Vegetation

The data for arsenic on vegetation has been plotted in Fig. 9. It shows that for either summer or winter samples, arsenic levels in the townsite, between the two mines, were between the levels of mine area samples. There was a reduction in deposited arsenic after the second Cottrell went into use.

Arsenic in Urine of School Children

Groups	Number of Children	Average Arsenic Level	Standard Deviation	Significance of Difference
A. Control[1]	47	0.0058	0.011	A vs. B P <0.01
B. Exposed Group December	40	0.063	0.041	B vs. C P <0.01
C. Same Group April	40	0.027	0.0063	C vs. A P <0.01

[1] Ottawa school children age and sex—matched.

Table 1

Urinary Arsenic

School children were examined and urinalysis done on a statistically valid group around seven years ago and within three years after commencement of discharge of arsenic to the atmosphere. The findings for two sets of tests at six month interval were compared against a group of Ottawa school children. These findings are shown in Table 1. Hospital records showed no effects due to arsenic and the school children were shown to be normal in health. Urines were significantly higher than normal in arsenic but not at toxic levels. Since that time one child has died due to drinking water made from snow. No other effects have been reported and a further clinical appraisal has not been made.

Conclusion

This study of environmental arsenic from discharge of smelter fumes has shown that even in remote areas, population concentrations develop when mining and smelting processes are successful. Thus, public health hazards can develop from discharged effluents. Operations must therefore be planned so as to provide protective measures. Uncontrolled stack discharge or discharge of wastes into nearby water bodies is not desirable. The study has shown the levels of environmental arsenic developing in relation to discharge loads and the urinary excretion of arsenic by exposed children. This review of the available data on the problem of disposal of arsenic wastes from smelters may provide a useful guide for future developments in this field.

Acknowledgment

It is desired to acknowledge the assistance of J. P. Windish in collection of samples and J. L. Monkman in analysis.

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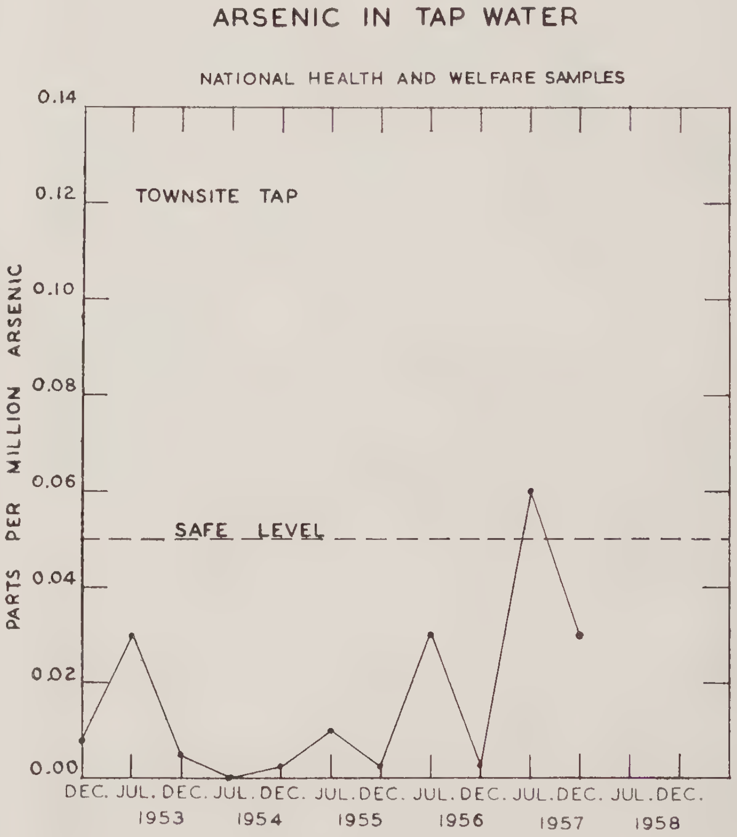


Fig. 3

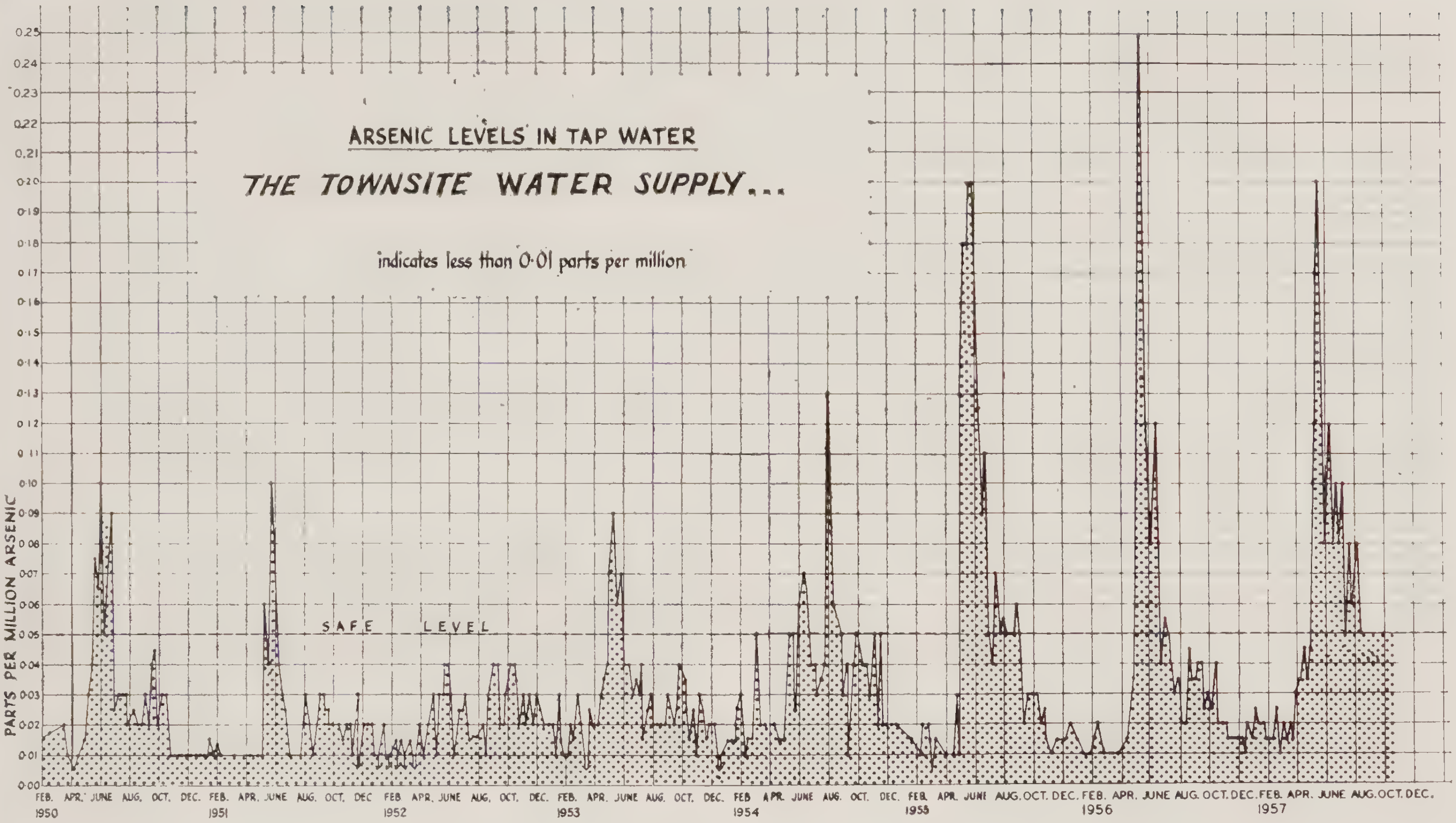


Fig. 4

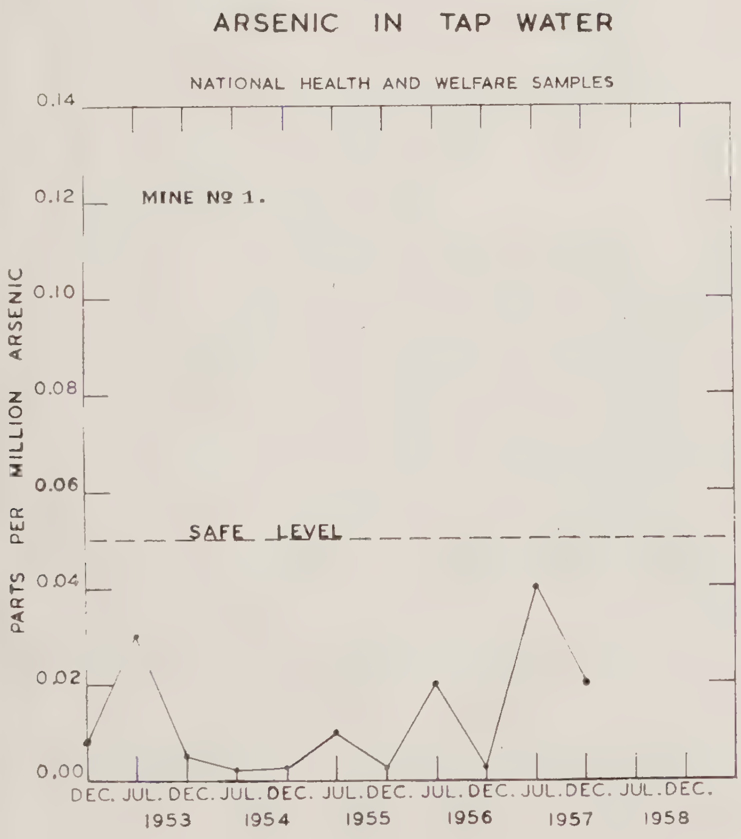


Fig. 5

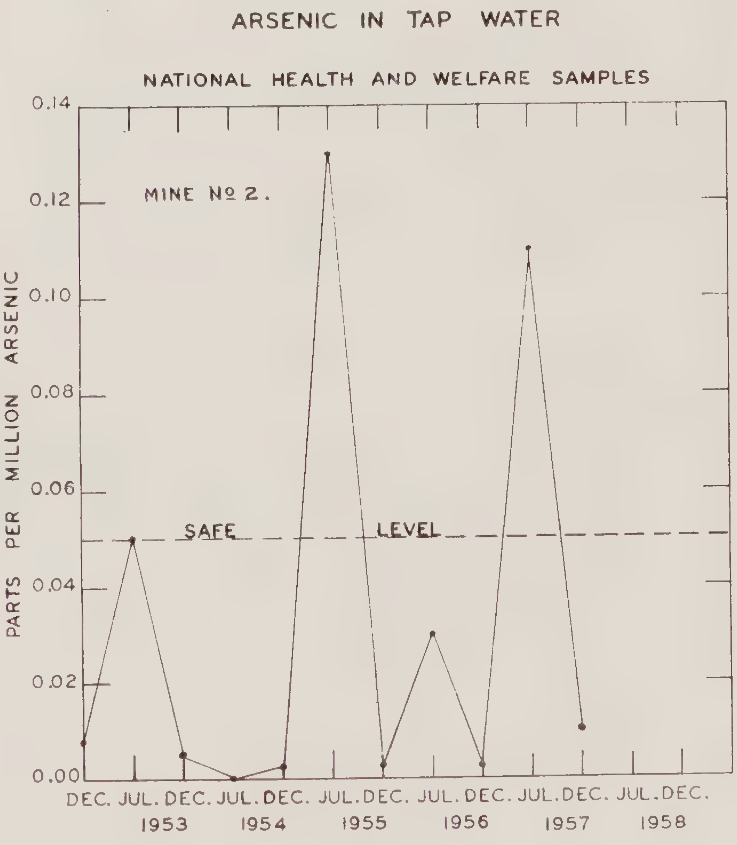


Fig. 6

III. 31

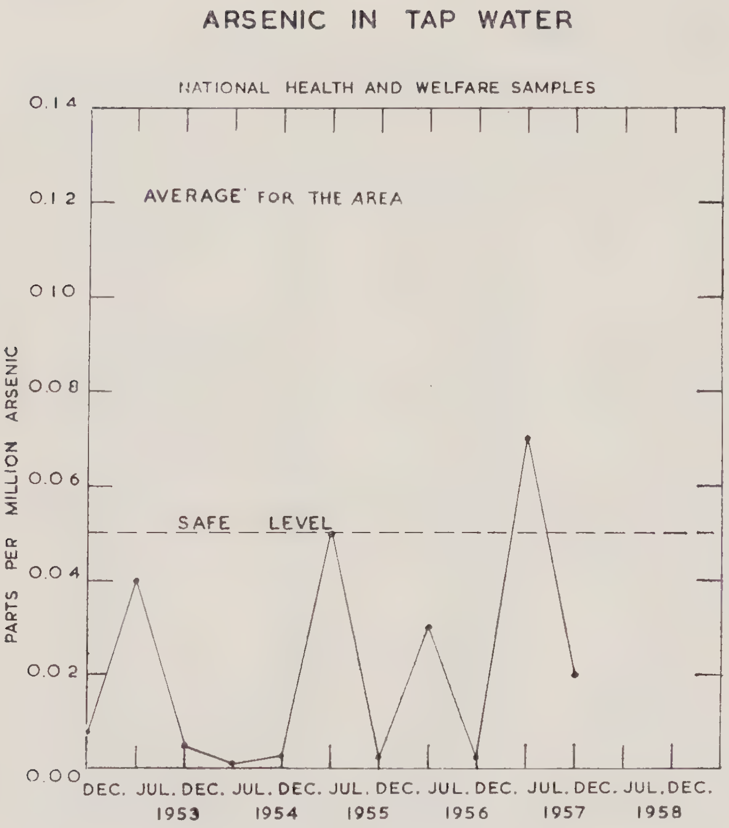


Fig. 7

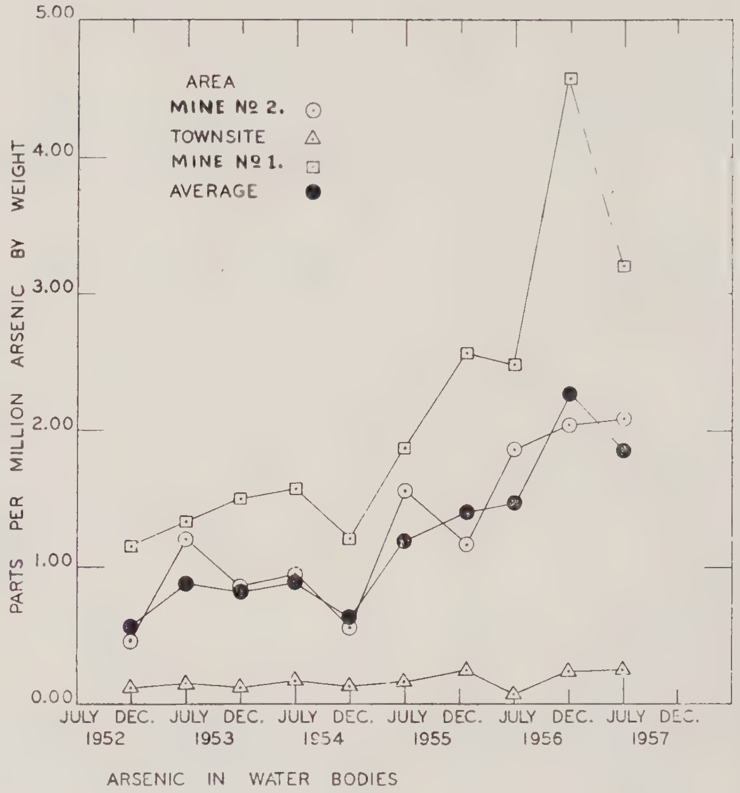


Fig. 8

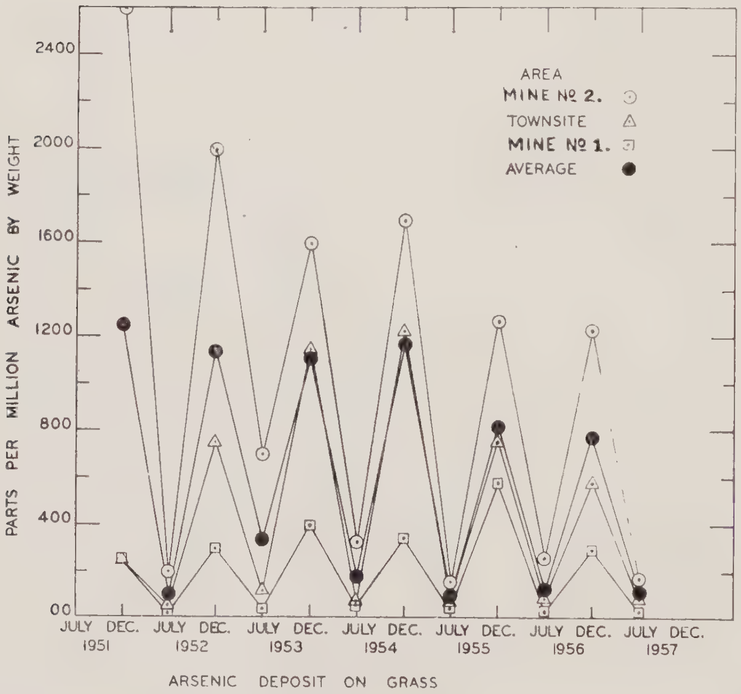


Fig. 9

III. 32

CHEAPER CLEANING EQUIPMENT FOR AIR POLLUTION CONTROL

Dr. HELMUT KETTNER, Scientific Assessor of the Bundesgesundheitsamt, Institute for Water-, Ground- and Air-hygienics, Berlin, Dahlem.

SUMMARY: The point is made that unnecessarily expensive solutions to air pollution problems are often put forward. An example is given in which a naphthalene works solved its pollution problem by a wet washing system, after a prohibitively expensive catalytic burning system had been suggested.

There is today in many countries a demand for the prevention of air pollution from new manufacturing centres for which 3 to 5 per cent and sometimes even more of the manufacturing expenses for the whole plant have to be assessed. The retention of the liquid as well as of the gaseous emissions is above all an economic problem. Certainly, each Manager would prefer a factory working " clean " and without annoying the neighbourhood. Experience shows that failure to do this is not due to a lack of good will. However, if the cost of the cleaning equipment is too high for the factory, Managers may shut their eyes to the matter. They will suddenly fail to see the smoke even though the sky is already black, and will regard badly smelling air pollution as pleasant, even though neighbouring residents may be nauseated. Managers of older plants in particular do not like the authorities to impose conditions on them, and their stereotype answer is " Up to now all went well." In only a very few cases is there no possibility for prevention of the air pollution and one may say that theoretically there is no such case.

The answer to the question of what cost can be borne depends, however, on the financial status of the factory and whether it will be able to afford to build supplementary cleaning equipment for air pollution control, which does not only mean no profit, but more frequently, additional expenses for its installation and maintenance. In many cases Managers rather agree to take the responsibility for the damages than to build cleaning equipment, for compensation means lower expenses, particularly if a special manufacturing process is used only for a limited time and one has to take into consideration that this manufacturing process will soon become obsolete because of other processes.

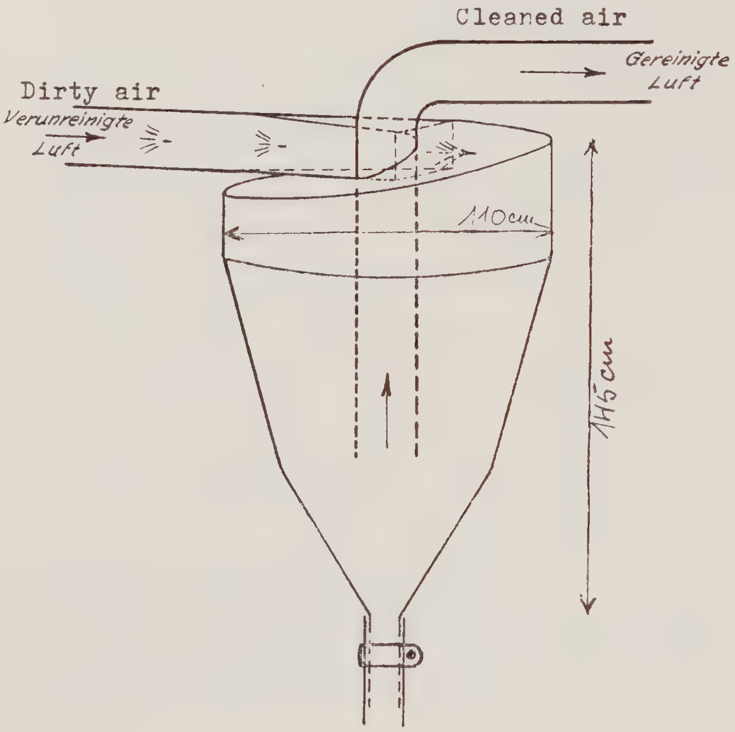
Furthermore, compensation will only be paid when the damage has been proved. This, however, cannot always be carried out correctly. On the other hand, it sometimes happens that neighbouring residents make unreasonable demands from which industry should be absolved. The general tendency, however, is that industry today intends to do its best for the prevention of air pollution. It is due to the above-mentioned high manufacturing costs that it is not always possible to put this into action. Therefore, we need cheaper, that means more economical, processes for the cleaning of emissions.

To develop such processes first of all the properties of the noxious substances to be taken out of the air pollution, have to be realized and this has not always been the case until now. Instead of looking for specific processes one is today inclined to clean all kinds of air pollution according to generally known processes. For instance it is normal to burn flammable air pollution constituents catalytically. However, catalytic burning is one of the most expensive processes that is used for combating organic substances. No firm, producing cleaning equipment for air pollution control, is to be blamed for recommending their processes. After all a lot of money was often invested in time-consuming and expensive development work, which of course, in the end should yield a profit. The following example concerning the recovery of naphthalene in an average sized factory, producing coal-lighters, may show you that it is sometimes possible to solve the air pollution problem by easy and cheap methods without charging a Manager with too high expenses.

In the factory referred to, naphthalene used for the production of coal-lighters is melted in a boiler at 194°F, and sawdust added. After saturation of the sawdust with the liquid naphthalene, the mixture is brought manually to the power press and remains under pressure till the naphthalene is solidified.

With the open manufacturing method of the lighter briquettes a great part of the naphthalene vaporizes into the workshop which has to be ventilated continually by a suction device. Formerly, the exhausted air was conducted uncleaned into the atmosphere, and this resulted in annoyance of the neighbouring residents.

Because of numerous complaints from neighbouring living areas about bad odour, the factory owner agreed to take measures for the abolition of this inconvenience. For this purpose he applied to a first class house, producing cleaning equipment for air pollution control. The firm in reply offered a catalytic combustion installation at a price of £3,500. This was the only offer the firm could make, and in spite of the owner's good intentions, the installation of the offered equipment was not carried out as the high price could not be paid.



As the complaints did not cease the Manager applied through the help of the Trade Supervising Department to the Institute for Water-, Ground- and Air-hygienics of the Bundesgesundheitsamt, asking for advice concerning the combating of naphthalene exhalations. After careful consideration the institute recommended a water-spray equipment which is placed in a cyclone to centrifuge the precipitate. The three nozzles (see illustration) with a water rate of flow of 20 litres per hour are arranged so that the spray direction of the water is against the direction of the crude gas entering the cyclone. The nozzles are fed directly from the water pipes. Such a wet cyclone has been installed in each of the three workshops.

About 10 kg of naphthalene, formerly conducted to the atmosphere, are now recovered every day in each workshop. As two rooms are usually working there is an average gain of 20 kg altogether. In autumn—and winter, that is to day, during the seasons which are most unfavourable to air hygienic conditions, three workshops were working and recovered 30 kg of naphthalene. In the case of full employment of the factory a considerable quantity of naphthalene is now kept, where it was formerly conducted via the roof into the atmosphere. Since the installation of the cleaning equipment, complaints by neighbouring residents about air pollution have ceased completely.

It is remarkable that according to the plans of the institute the cleaning equipment was executed by a rather small plumbing firm for not more than some hundred marks. Working costs for its maintenance are very low as they only involve the water consumption. For eight hours of work this is 480 litres or about 1/2 m^3 = 20 Dpf. each cyclone. The factory on an average gains, however, 20 kg of naphthalene each day, which not only covers the current expenses but beyond that, amortization of the equipment in a very short time. Catalytic burning, however, would not only mean high charges for the installation of the cleaning equipment but additional charges for its operation. Furthermore, no naphthalene would be recovered as it is burnt during the process.

This example shows you as well that well-known firms producing cleaning equipment are not always capable of making suitable proposals for the cleaning equipment for air pollution control. The catchword " catalytic burning " is sometimes even used in cases having no application at all. Of course, it cannot be said straight away whether water will be a proper precipitant for the noxious air pollution constituent. And concerning naphthalene it was uncertain whether it could be precipitated with water, since naphthalene, representing pure hydrocarbon, is a nonhygroscopic substance throughout. Optimum conditions for the precipitation of an aerosol from air are presented, if the aerosol is wettable by a finely divided liquid and in a precipitated state will spontaneously segregate again. Solvents for dissolving the aerosol are not very appropriate as this would mean a subsequent dissociation of the dissolved aerosol from the solvent, by way of distillation. Supposing the surface properties of aerosols are constant, variations of the liquid will allow enough latitude to find liquid reagents for each substance, which correspond to the conditions required. Water is the cheapest liquid as its activity may be varied by addition of surface-active substances and size of drops. The reaction of naphthalene upon water is interesting in so far as it is not wettable by water, when crystallized off the melt. Off the gaseous state, however, it is wetted to a great part by little water-drops, thus representing the precipitate capability of naphthalene with water in general.

It is regrettable that till now these systems have been so little investigated. However, some references suggest that one may find for several substances behaving as aerosols, respectively occuring in gaseous states, as for instance oil—and tarsteam, organic solvents and so on, a proper aqueous compound, fulfilling the above-mentioned requirements. The spray method with a proper addition of surface-active substances should also further the precipitation of dust and solubility of gas, and economically it will be superior to the cleaning processes for air pollution control which are used at present.

THE PROBLEM OF COLLECTING DUST AND GASEOUS MOISTURE AT EMISSION POINTS IN RELATION TO AIR POLLUTION

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SUMMARY: The paper deals with the problem of dust and fumes from industrial processes other than combustion. It points out the desirability of picking up the pollution at source by means of hoods, etc., and cleaning the air drawn in before ejecting it to the atmosphere. Design considerations relating to suction hoods and ducts are discussed.

There is no need to point out the growing interest of Britain, France and all other highly developed industrial countries, in questions of " air pollution ".

For proof of this interest I seek no further than the present conference which has done me the honour of accepting my paper.

Without going into details, I will recall that atmospheric pollution is shown in two ways:

In the atmosphere generally. Partly by waste material from natural phenomena (wind erosion, volcanic ash, pollen, animal or vegetable refuse, etc.) Partly by waste material ejected by industrial furnaces or domestic fires, internal combustion engines of vehicles, etc.

In places of work. In yards, workshops and industrial premises, by dust and fumes caused by handling certain products, and by the machining or processing to which they are subjected.

Evidently we can only contend against pollution produced by human activities. This is a very serious, major problem which all countries are seeking to solve by promulgating acts, decrees and by-laws which are more or less thorough and more or less strict.

We will leave on one side the question of dust and soot caused by combustion, also of various pollutants ejected by factory chimneys, so as to confine our study to dust, gaseous moisture, fumes, etc., produced at places of work and directly causing pollution.

In fact a place of work does not necessarily imply a workshop or premises which are virtually enclosed; such a property may extend over a considerable surface area, often with plant generating dust in different places and in the open air or having little shelter. Such plants are:

Coke Ovens;
Cupola furnaces;
Converters for steel works;
Breakers and mixers for coal ore, food stuffs, clinkers, etc.

Even if emission occurs in enclosed premises or workshops, air purification for hygienic working conditions will necessitate a general ventilation system, or preferably, as we shall see, collection at the source of emission. The polluted air will in any case be ejected into the atmosphere, but with arresters it will be possible to apply suitable treatment to ensure that the dust is trapped by filters or dust removing apparatus, or by physical or physico-chemical treatment, to neutralize the noxious gases, etc.

It, therefore, appears that to control dust, gaseous moisture or fumes if not possible to prevent them at their source—we must first consider their collection, which might be defined as follows:

" A method which, with suitable appliances, allows the noxious or offending products to be trapped into an air circuit by means of a piping system discharging into the atmosphere:

Solids (various types of dust);
Liquids (droplets or mist);
Gases (metallic exhalations or steam);

resulting from an industrial operation to prevent these products from spreading in places of work or the environs, causing offence or danger to the workmen or occupiers or to the neighbourhood, and leading to damage, etc."

Furthermore, dust, droplets or fumes are often mingled.

What operations, machines or control points produce emission which need collecting?

As must be admitted they are innumerable. In addition to the examples above, we will quote some at random though without claiming this list as definitive:

Mill wheels, lapidary lathes, polishing wheels, cutting tools;
Machines for working wood;
Apparatus for grinding, discharging and for trimming foundry castings;
Booths for spray painting, sanding or granulating;
Skips, conveyor belts, tipping points;
Bagging operations;
Metal smelting (zinc, bronze, etc.);
Sites for welding, galvanizing vats, pickling and degreasing baths;
Removal of gaseous moisture from paper machines, various tubs, etc.

By reason of the declared aim and of the means pursued to achieve it, collection of pollutants interests both the hygiene expert and the industrialist.

In fact, the principle and the realization of such collection are of fundamental importance, to achieve maximum efficiency with minimum costs for installation, maintenance and operation.

In spite of high extraction capacity, an ill-designed, ill-fitting hopper hood or chimney cowl will lead to escaping fumes and dust, cumbersome pipe connections, rising power demands, etc.

How is collection equipment installed?

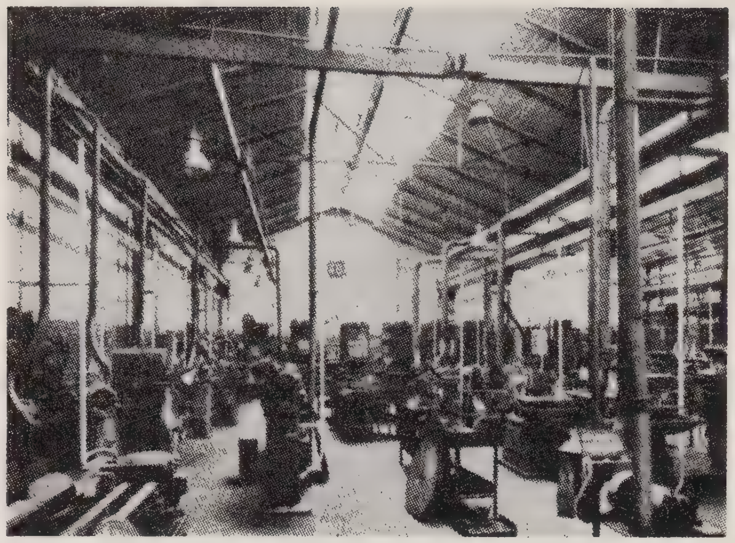
Essential requirements are:

The collecting appliance itself;
A system of pipe fittings;
A ventilator to ensure the necessary air flow within the circuit to suck in the dust and fumes and convey them outside;
To the greatest possible extent, apparatus for dust elimination, filtering, neutralization or dilution.

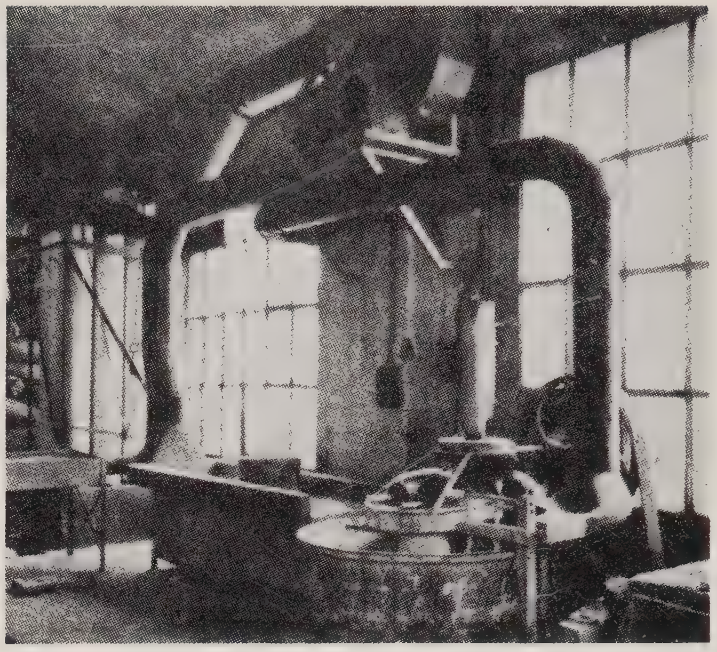
As specified, we shall only examine here, and rapidly at that, the collection system itself.

The ideal solution would obviously be to encompass the pollution source in a virtually steam-tight enclosure, coupled to an exhaust circuit.

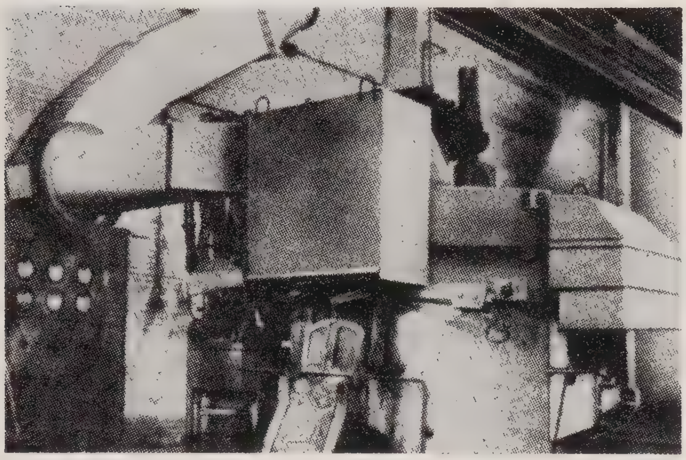
Apart from plant whose structure contains such



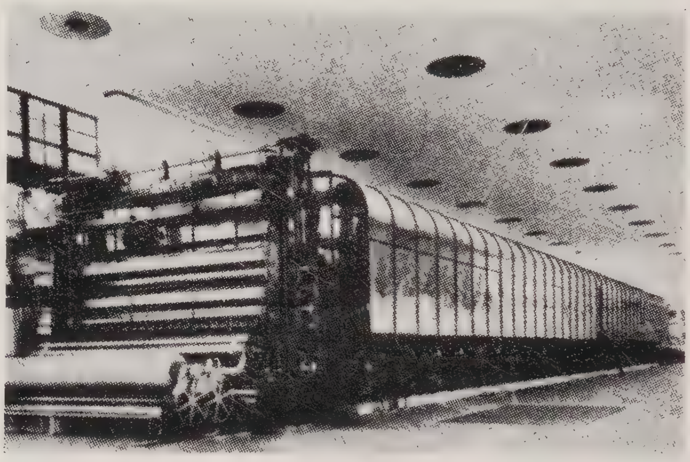
Dust extraction for machine tools



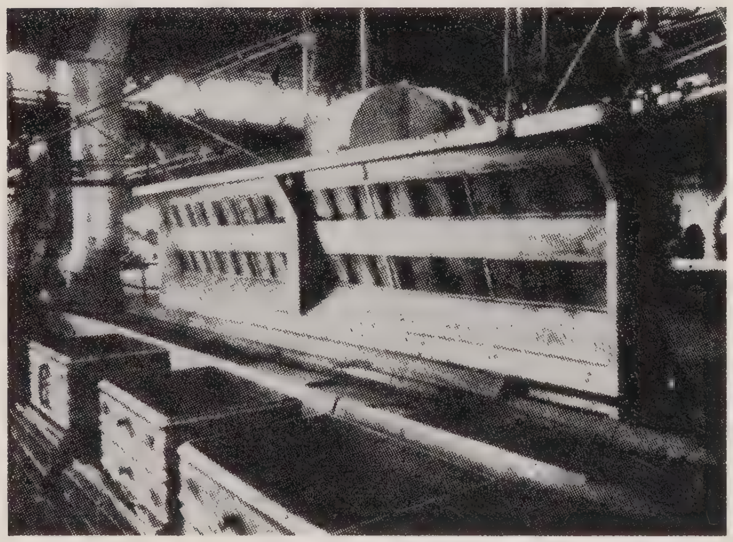
Extraction hoods over mixer and working table (Kieselguhr dust)



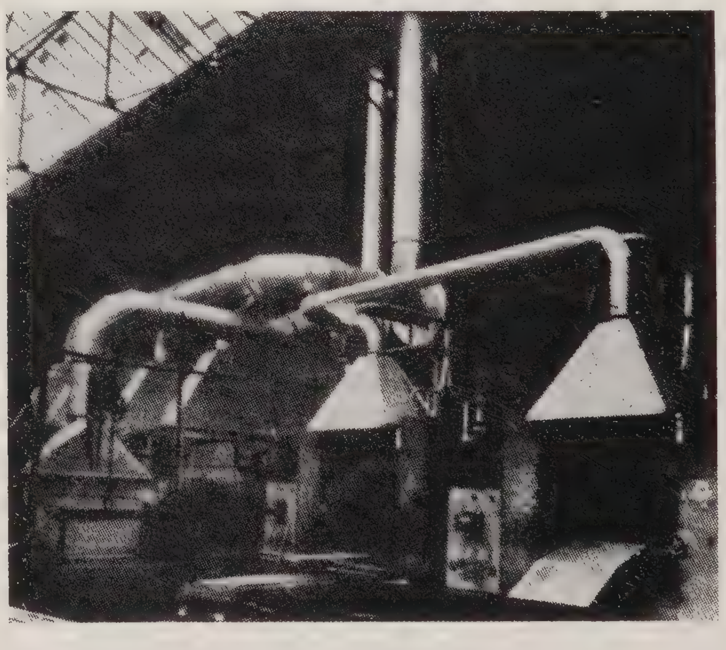
Hood over electric melting furnace



Steam and vapour extration hoods, papermaking machine



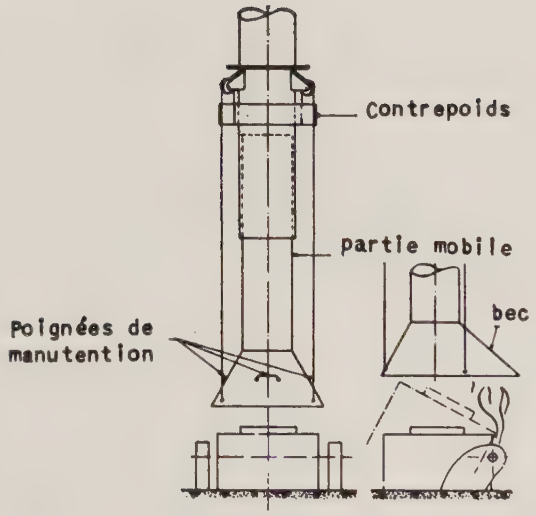
Lateral extraction hoods, stripping furnace



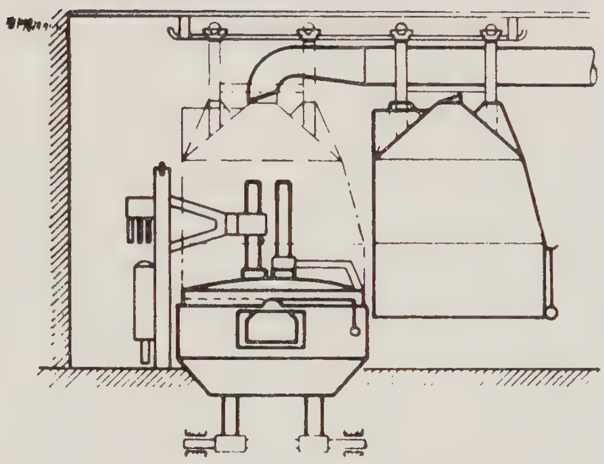
Hoods over heavy oil-burning kiln

Different types of Extraction Hoods and Cowls

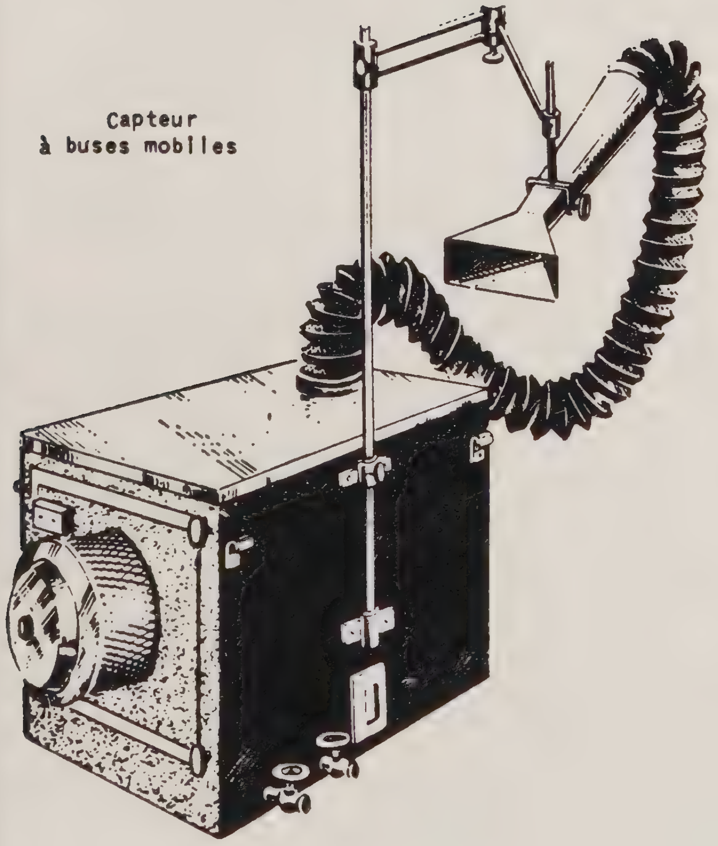
III. 33



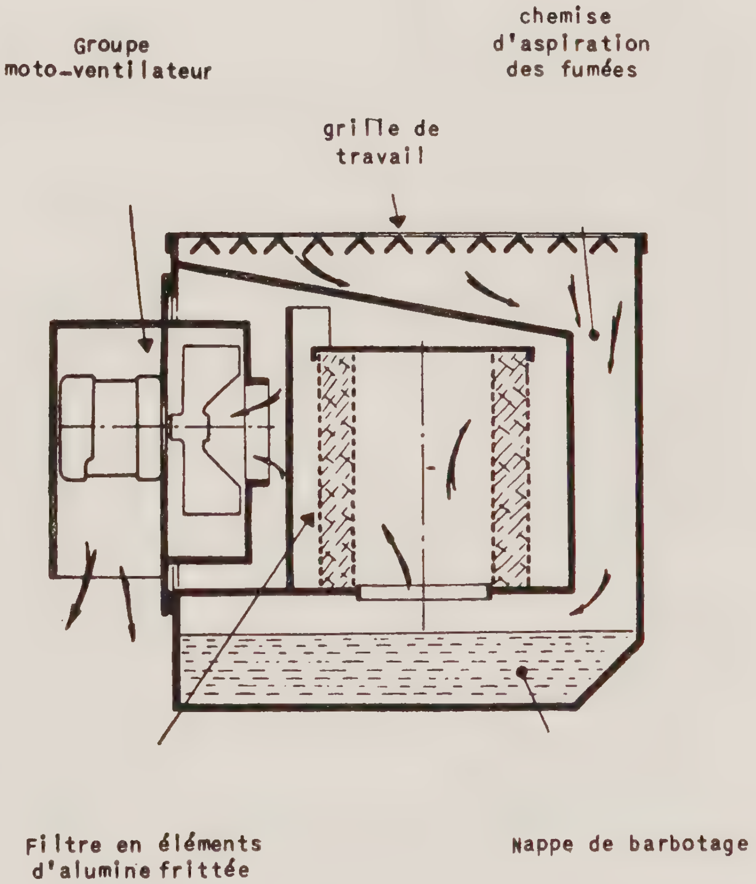
Hotte télescopique
sur four de fusion basculant



Hotte coulissante
sur four électrique



Capteur
à buses mobiles


Groupe moto-ventilateur
chemise d'aspiration des fumées
grille de travail
Filtre en éléments d'alumine frittée
Nappe de barbotage

Dispositif d'aspiration
sur table de soudure

arrangements (boilers and furnaces which collect the whole outflow of smoke including dust), systematic installation of a suitable circuit should be the general aim, and we should strive to approach the ideal condition explained above.

It should be noted that this solution by trapping in an enclosed space can only be used in certain special instances where only small quantities of products have to be handled, or where their poison content makes the procedure imperative. This is so with operations involving beryllium or radioactive bodies for which will be used virtually steam-tight hooded apparatus or boxes fitted with gloves.

More often we have to be satisfied with placing an air exhaust near the emission source, worked by a suitable arrestor. While extracting the maximum of the dust or fumes produced, this machine will leave free an adequate working area to allow easy feeding of materials for processing, their handling, the execution or supervision of operations required, etc.

When fumes or dust are already suspended in a carrier fluid, it will suffice so far as practicable to trap the fumes or the fluid, avoiding leakage on one hand and intake of excess air on the other.

Generally speaking we must begin by placing the dust in suspension. This can prove fairly difficult either with dust in a large mass (due to its size or specific gravity) or with dust tending to be driven out by the force which animates it at the time of production (e.g. metal particles torn off by the grinding wheel).

In practice there is a double problem to solve:

Form, and
Calculation of air feed capacity.

Form

The form should, above all, be suited to the apparatus which needs to be served, and we must remember the basic principle that the dust should always be trapped as close as possible to the point of production.

The different arrestors take the form of cowls, air shafts (sometimes reduced to a single slit) and hopper hoods.

Suction may also be carried out on wide surface area built into the machine and with grill type openings, in a perforated iron sheet (e.g. a welding table).

The form and the position of the arrestor must be determined in relation to how the fumes or dust are produced.

Light fumes which by their nature tend to rise vertically;
Heavy fumes which tend to fall;
Dust particles projected in a well defined direction (planing machine, grinding wheel, polishing band, etc.).

Taking into account certain imperative conditions such as:

Handling of materials;
Access.
Worker's task;
Supervision, etc.

For these reasons we see telescopic or pivotal hoods, arrestors with moving caps or sections, jig apparatus, etc.

In fact, attention must be paid equally to air movement due to general ventilation, controlled or not (draught), and to extraction from the plant in question or from neighbouring plants.

To respect the first principle put forward as essential, it would be desirable to install an arrestor plant all round the emission source. It would also be desirable, for reasons both of efficiency and of economic working, to isolate a certain volume so that its communication with the outer air may be as little as possible.

This ideal condition is achieved, for instance, by the box fitted with gloves or the fume cupboard, where one may work with a virtually sealed container.

Certain hood fittings on fixed grinding wheels, for instance, will allow a small amount of contact with the air, just enough to allow the object to be ground to have contact with the biting edge of the wheel.

By contrast, in other instances, the suction plant must be some distance from the production point, because of the large size of materials to be handled, or because of the complex operations to be undertaken, etc. For example, a series of pickling baths placed side by side, and in which the plates will be guided by a monrail placed in the axis of the baths, will not allow fixture of the hood above the bath or of the air vent on the long sides. It must suffice to place an air vent on the short sides of the troughs: and moreover, to ensure its efficiency with a reasonable air flow, its action must be combined with that of a blowdown device placed at the other end.

Calculation of Feed Rate

With the form and the function of working conditions already determined, how should the feed rate of air extraction be calculated?

We can leave aside a certain number of machine tools for which the type of cowl has already reached its definitive stage. For them the feed rate norm, designed exclusively for the type and dimensions or capacity of the machine, have standard values adopted almost uniformly by all their manufacturers.

Generally speaking, and where the type of appliance has been determined, how should we calculate the feed rate for air extraction?

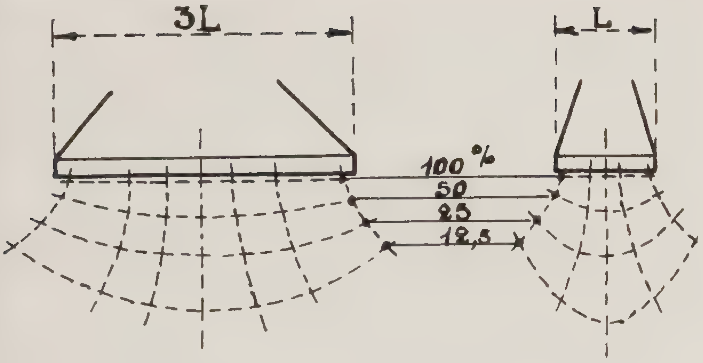
Here there are many theories available, each manufacturer or erector of plant having his own method which is suitable for his purpose; consequently, in solving the same problem we are faced with diverse solutions which may lead to vary different feed rates.

In any event, if we analyze the phenomenon of fume and dust feed rate, we can say that basically the feed calculation consists of:

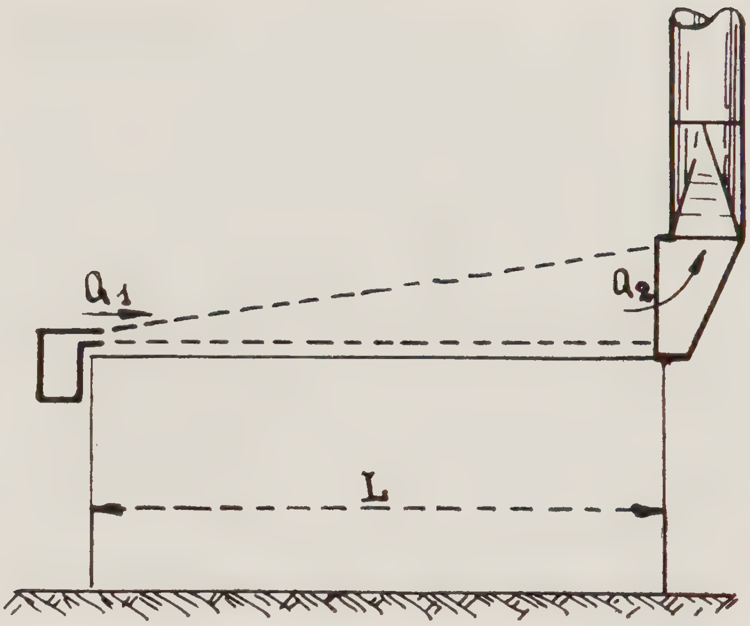
Determining an imaginary casing surface, continuing the inner sides of either the hopper hood, the cowl or the air shaft surrounding the emission source of the dust or fumes;
Inducing across that surface a velocity which will not allow dust or fumes to escape, but will on the contrary ensure that they are carried along.
This velocity must, of course, take account of many factors:
  Positive or negative rising speed of the fumes.
  Falling speed of the particles in the air (Laws of Newton or Stokes, according to particle sizes).
  Speed and initial direction of the particles, when they are driven out mechanically.
Make sure also of checking:
  Air movements on the premises which may be due to central heating, ventilation or draughts;
  Air movements which may result from operating the machine concerned (e.g. conveyor belts or disc wheels).

It is quite clear that the ideal casing surface should not be chosen haphazard, but should consist of a floor area literally crossed by air streams. And in this connection it is imperative not to lose sight of the laws governing air flow near a suction point, which are very different from those at a blow point.

The diagrams below show the distribution of



REPARTITION DE L'ASPIRATION A L'ORIFICE D'UNE HOTTE RECTANGULAIRE



Hauteur de Bouche H = L tg 10° = 0,2 L

Débit aspiré Q2 = 0,5 à 0,75 m3/sec par m2 de bain

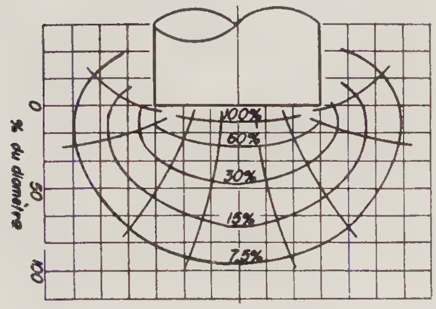
Débit soufflé $Q1 = \frac{Q2}{0,3\ L\ E}$

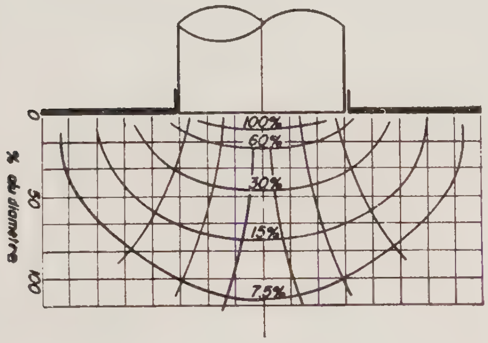
L = portée du jet = largeur du bac

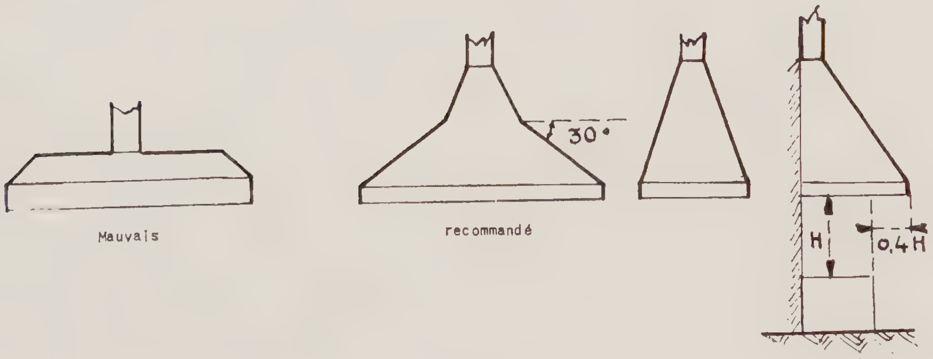
E = facteur d'entraînement

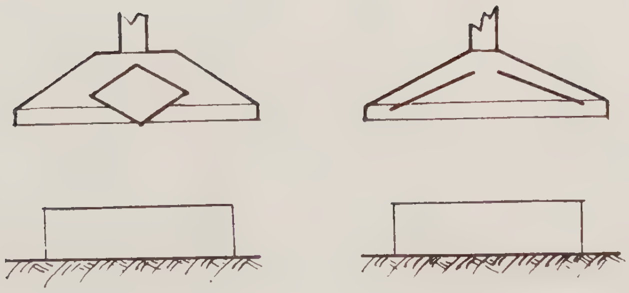
E = 2 pour L ≤ 2m50
= 1,4 " L de 2 à 5 m
= 1 " L de 5 à 7 m

Vitesse du jet : 5 à 10 m/sec.









gaseous streams round a circular suction point with and without a shield, also extraction through a rectangular hopper hood. It is proved that the extraction force reduces extremely quickly as it recedes from the suction point and that, for instance, at a distance of only one diameter, the velocity in the axis of the nozzle is already less than one-tenth of the velocity inside the nozzle itself.

Given a velocity of 10 m per sec at the nozzle, at a distance of one diameter the velocity in the casing surface will be slightly greater or less than 0·75 m per sec according to where the nozzle is free or fitted with a flange or a shield.

On the contrary, the directional force is much better preserved in the exhalation; the vein spreads out in the form of a cone or sheet at an angle of 12° to 20° and, as compared with the velocity of 10 m per sec envisaged above, the velocity of the outflow jet may only fall to 0·75 m per sec at a greater distance than 17 m for an exhalation shaft of φ 360, or a distance of 50 times the diameter.

It is therefore recommended that, as often as possible, exhalation and suction be combined so as to bring about a low discharge of dust or fumes in the zone of influence at the suction point, when by force of circumstances this point is some distance from the production point. This is preferable to providing wide suction points with high extraction speed. These are factors conducive to high speed rate and considerable absorptive powers.

These results from experience and measurement support the essential principle on which attention has been focussed: extraction plant should be sited as close as possible to the production point of the dust or fumes.

The diagrams above show a certain number of hopper hood types in which, because of their wide cross-section, and true level of extraction has been lowered by means of certain devices.

With the same purpose always in mind, but where perhaps handling arrangements demand a level at the foot of the hopper hood some distance away from pollution source, we can place the extraction point on the rim of the moving or flexible caps. It will also be an advantage to make one at two or even three sides of the hood, thereby reducing the volume of extraction and avoiding the extremely injurious effects of draught.

By this rapid survey I hope to have focussed attention on the importance pertaining to suppression equipment, the full use of which—often alas, difficult! avoids not only the escape of dust and pollutants near the machines or equipment which cause them, but also (when these elements are canalized by their driving force into a suitable circuit) enables them to be contained or neutralized. This operation is sometimes profitable for the industrialist; it is *always profitable* for the population at large as it contributes towards less air pollution.

ELIMINATION OF ACIDIC SMUTS

B. LEES, British Petroleum Company, Great Britain

SUMMARY: As the result of scientific research, it has been shown that acidic smuts, which sometimes fall in close proximity to boiler chimneys can be formed by stack solids adhering to condensation on cool surfaces, such as ducts and metal stacks, through which the flue gases pass.

Examples are quoted showing how this problem has been solved by:

- **(a) Operating the plant in such a manner that the SO_3 formation is reduced to a minimum.**
- **(b) Designing the plant to eliminate cold areas in the gas passes where condensation may occur.**

The importance of making measurements to control experiments to overcome this problem is stressed, and simple but effective methods are indicated.

A form of pollution which has received increasing attention is the deposition of relatively large acidic soot particles near industrial chimneys. Although the weight of solids falling is not excessive, the particles, commonly known as smuts, may cause a local nuisance because of their acidic nature and size (they may be up to ¼ in. diameter). They may damage paintwork and stain light-coloured absorbent surfaces.

Analyses and microscopic examinations have shown that smuts usually consist of an acid bearing agglomeration of black particles, sometimes with a white crystalline matrix of ferrous sulphate. A typical smut from an oil-fired boiler is shown in the photograph Fig. 1.

Partially dispersed *Fig. 1* *Fully dispersed*

Method of Formation of Smuts

Sulphur, present in all industrial fuels, is oxidized almost entirely to SO_2, but a small portion, usually less than 2%, may undergo further oxidation to SO_3.

SO_2 does not affect appreciably the dewpoint of the flue gases, but SO_3 may raise the dewpoint of flue gases from 120° F. to 250° F.–300° F. Consequently deposition of sulphuric acid may occur on surfaces in contact with flue gases when the surfaces are below the acid dewpoint. This may result in corrosion of the cool surface.

Recently work by the British Petroleum Company and the British Launderers' Research Association[1] has shown that acidic condensation may also be responsible for the formation of the acidic smuts described above. If condensation occurs on a cool surface, such as the surface of metal stacks, some of the solid particles carried in the flue gas stream stick on the moist acidic surface and gradually form a thin film. When fuel oil is fired satisfactorily the concentration of stack solids is low, below 10 grains per 100 cu. ft., but there are, however, still sufficient particles to settle on the acidic layer and form smuts. Fitting grit arrestors will not overcome the problem.

Condensed acid may also attack the metal and form a crystalline matrix of iron sulphate round the stack solids. If there is a change in temperature or gas velocity the layer of acidic bonded material may flake off and break up into smuts which are then carried out of the stack by the flue gases and fall locally. Evidence available shows that smuts generally form where the flue gases are in contact with cool metal surfaces after the induced draught fan.

To prevent the formation of smuts:

- (*a*) the plant should be operated in such a manner that the minimum quantity of SO_2 is converted to SO_3.
- (*b*) the plant must be designed to eliminate cold areas in the gas passes where condensation may occur.

Operation of the Plant to Reduce Acid Formation

Research[2] has shown that by operating oil-fired plant with the minimum quantity of excess air, consistent, of course, with good combustion conditions, the formation of SO_3 may be considerably reduced. Generally under practical conditions many boilers may be operated with over 13% CO_2 without causing smoke.

A typical curve illustrating the relation between CO_2 and SO_3 production is shown in Fig. 2. It should also be noted that reducing the quantity of excess air also increases the efficiency of the plant.

Elimination of "Cold Areas" in Chimneys, Ducting, etc.

Measurements taken with thermocouples or temperature-indicating crayons should first be used to determine the location of "cold areas," that is where the surfaces in contact with the flue gases are below 250° F.

It has been found in practice that even with flue gas temperatures as low as 300° F., ducting and stack designs in brick, concrete or steel are possible such that cold areas are avoided and therefore smut emission does not occur.

One method for eliminating cold areas was described in a paper referred to previously[1]. Here it was found that by surrounding a steel chimney with an aluminium shield, as illustrated in Fig. 3, the temperature of the walls of the steel stack was raised above that at which serious acid condensation occurred and smut emission was entirely eliminated. More than twenty metal chimneys have now been shielded in this way, and all the plant operators have reported satisfaction with the reduction or elimination of smut emission. Another example is shown in Fig. 4. Detailed results of shielding stacks on three plants are given in Table I.

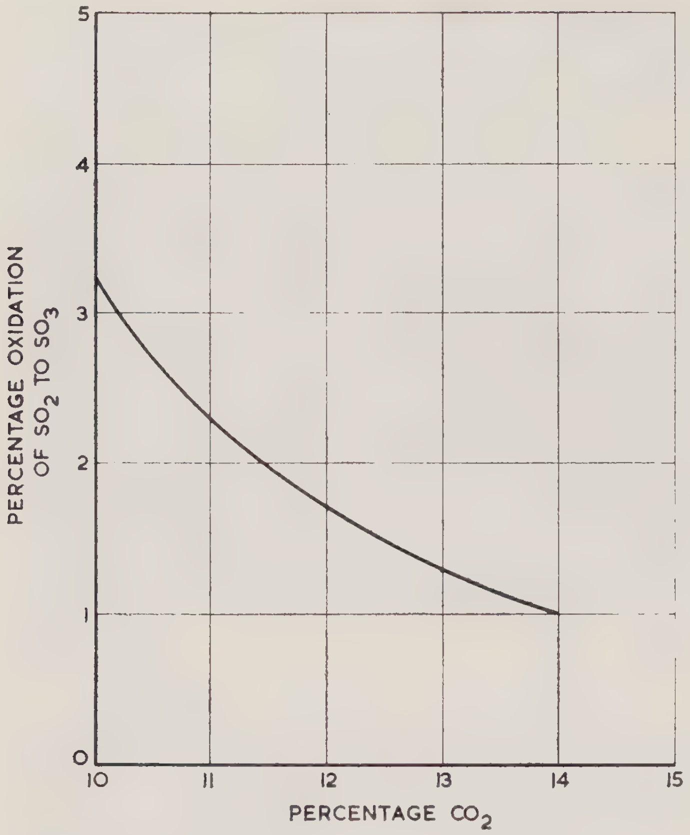


FIGURE. 2.

PERCENTAGE OXIDATION OF SO_2 TO SO_3 IN FLUE GASES WITH COMBUSTION CHAMBER OUTLET. VARIATION WITH PERCENTAGE CO_2

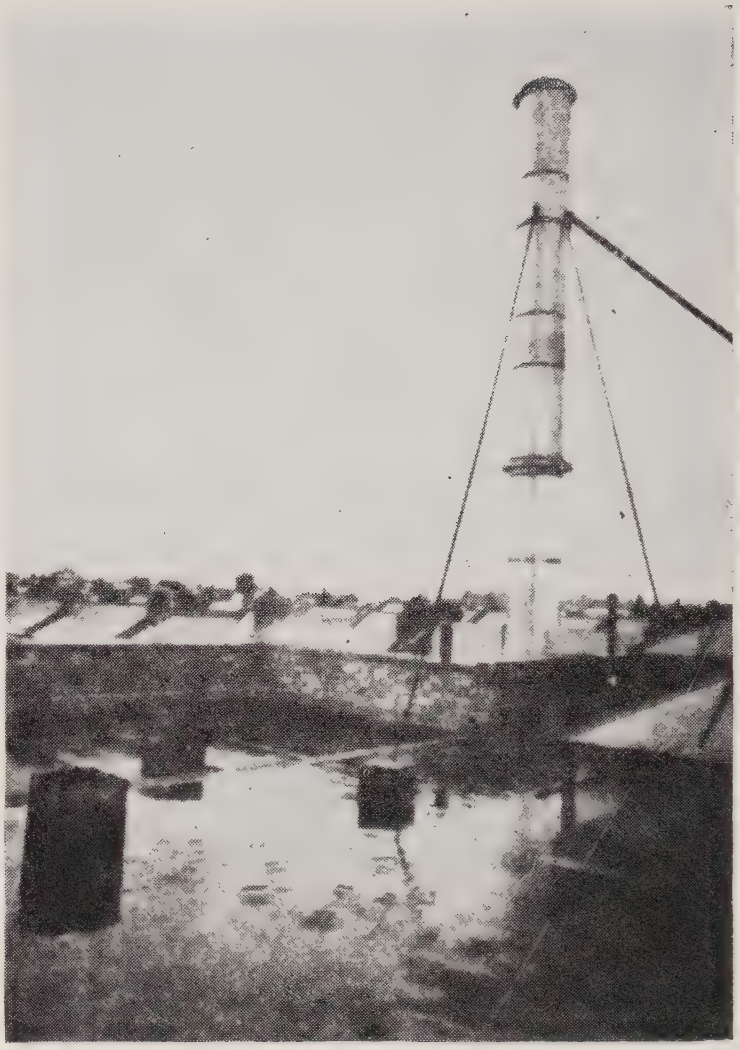


Fig. 3

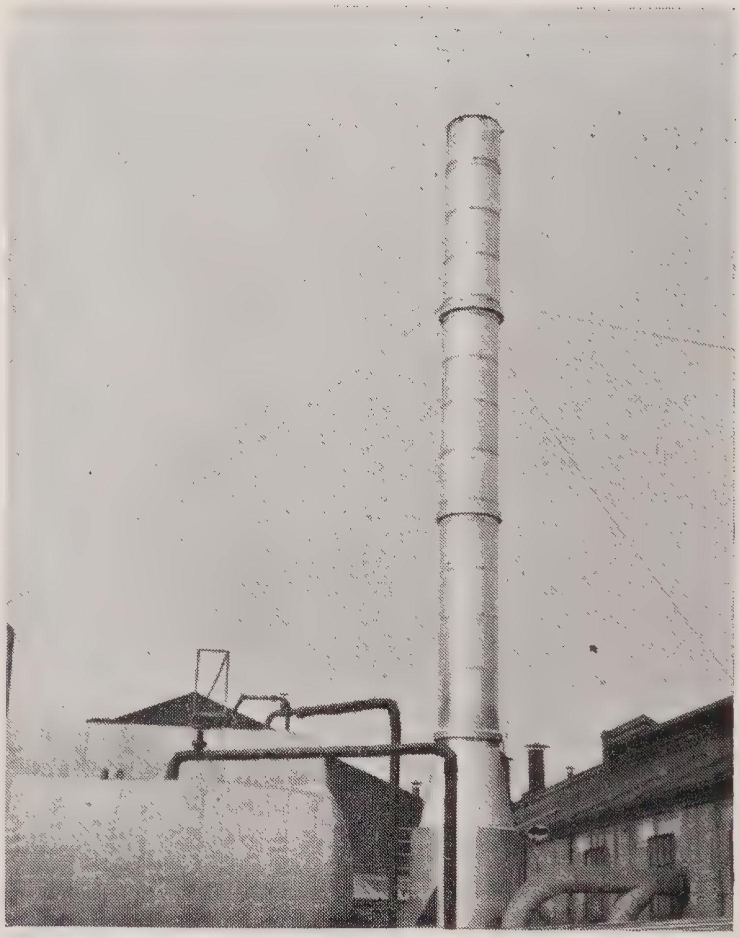


Fig. 4

Smut emission from brick stacks is only infrequently observed and, if the burner is operating satisfactorily, smuts occur either because excessive air infiltration occurs between the boiler exit and the stack causing localized cooling or because metal ducts between the boiler and stack are unlagged and have "cold areas."

Smut emission has also been reported from large concrete stacks, such as at electricity generating stations. Providing combustion conditions are satisfactory and ducting is adequately lagged, smut formation is probably due to localized cold areas within the stack caused by air vents through the concrete stack and inner brick lining. It is claimed that the use of air cooling prevents overheating of the concrete stack. Designs are available, however, for the construction of concrete stacks without air vents through the brick lining. It is the author's experience that with the latter form of structure smut emission is not a problem even with boilers operating at high efficiency with a low flue gas exit temperature.

Measurements of Emission

As in all experimental work on atmospheric pollution, it is essential to measure quantitatively the effect of a change in operation and not to merely rely on visual observation.

As shown in Fig. 3, open boxes 1 ft. high and with an area of 1 sq. ft. were placed close to the stacks in areas where smuts were frequently observed. Each day the number of smuts which collected on the wooden base of the boxes were counted, the observations being made for one month before and after the modifications. Results of some of these observations are included in Table II. Where the concentration of smuts is lower it will be necessary to use boxes with a greater surface area.

Table I

Effect of Shielding Stacks on Three Boiler Plants

Location of Stack	*Boilers*	*Flue Gas Temp. Stack Inlet*	*Effect of Shielding*	
			Stack Metal Temp.	*Smuts*
Laundry	1 Vertical boiler ...	650° F.	Raised from 140° to 390° F.	Smuts caught in 4 boxes reduced from 200 per week to zero
Factory	6 Economic boilers ...	430° F.	Raised from 220° to 400° F.	Smuts caught in 6 boxes reduced from 2,528 to 112 per 100 days (see Table II)
Milk Factory ...	1 Packaged boiler ... 2 small water tube boilers	300° F.	—	Smut emission complaints ceased

Table II

Effect of Shielding Stack on Particles caught in Collecting Boxes

6 Boxes each 1 foot square—Number of Smuts caught in 100 days

Size of Smuts	*Unshielded Stack*	*Shielded Stack*
$\frac{1}{16}$ in.	1,305	54
$\frac{3}{32}$ in.	663	25
$\frac{1}{8}$ in.	358	17
Greater than $\frac{1}{8}$ in.	202	16
TOTAL	2,528	112*

* Very likely these may have been from other sources of pollution.

Conclusions

Acidic smuts can cause a serious local nuisance near to the source of emission. This form of pollution sometimes attracts public attention rather than other far more obnoxious, but less apparent, forms of pollution.

It has been shown that by scientifically operating and designing the plant to:

(*a*) reduce the formation of sulphuric acid in the flue gases

(*b*) eliminate "cold areas" from ducts and chimneys.

smut emission may be successfully prevented even with plant operating with a low flue gas exit temperature.

The author wishes to thank the chairman of the British Petroleum Company for permission to publish this paper.

References

[1] H. A. Blum, B. Lees and L. K. Rendle. *J. Inst. F.* 1959, **32**, 165.

[2] A. Dooley and G. Whittingham. *Trans. Far. Soc.* 1946, **42**, 354. B. Lees. *J. Inst. F.* 1956, **29**, 171.

III. 35

SULPHUR IN THE AIR

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SUMMARY: Apart from smoke, sulphur (mostly in the form of sulphur dioxide) from combustion is the main deleterious constituent of air pollution. A large proportion of the sulphur comes from the combustion of coal and oil. Half of the sulphur in coal is organic and difficult to remove, but much of the remainder could be removed by adequate coal preparation. Oil is also a large source of sulphur, especially the residual oils burnt as fuel. Modern processes should make it possible to remove this sulphur. A dry process is needed for removing sulphur from the flue gases of large installations. A close study should be made of the economics of obtaining sulphur from flue gases.

Since June 1958 the Clean Air Act has been in full operation. *Clean Air* has become a slogan, has hit the headlines and has made a large body of the public conscious of the evils of pollution of the atmosphere, at any rate of the visible impurity, smoke, which succeeding generations had accepted as an inevitable concomitant of daily life. The Beaver Committee on Air Pollution, on most of whose recommendations the Act was based, had recognized that smoke, grit and dust emitted from domestic and industrial chimneys were not the only contaminants of air but that the invisible gaseous impurities had to be considered. Of these, in the Committee's view, the most deleterious product of the combustion of fuels is sulphur, present in the form of its oxides, mainly sulphur dioxide.

After examining various untried proposals and some technically proved processes, the Committee came to the conclusion that there was then (1954) no prospect of the emission of sulphur oxide from general industry or domestic fires being substantially reduced, but that this was an important issue which required further attention and intensive research. Consequently, Parliament did not feel justified in making provision in the Clean Air Act for fixing limits of, or penalties for, the emission of sulphur acids arising from the combustion of fuels.

The discharge of noxious or offensive gases from chemical and similar processes, as from sulphuric acid plants, registered under the Alkali Act—originally passed in 1863 and from time to time amended, extended and consolidated—is, of course, strictly controlled by a corps of competent inspectors, recently enlarged. But, whilst nuisances created from such operations may be of considerable local importance, they are of relatively little significance as affecting the purity of the country's general atmosphere.

What is quantitatively of real importance is the release of sulphur compounds when fuels are burned. Indeed, the biblical combination of brimstone and fire with its dire consequences finds its counterpart in modern civilization. All fuels, except perhaps wood, contain appreciable amounts of sulphur. In whatever chemical combination it occurs, sulphur is liberated on burning in the form of sulphur dioxide, just as carbon, the principal fuel component, burns to carbon dioxide. Whilst carbon dioxide is a normal constituent of air and has a beneficial function as a promoter of plant life, sulphur dioxide, which is eventually converted to sulphuric acid, will attack metals, stonework, and fabrics, causing corrosion, decay and rotting, and will inhibit the growth of vegetation. One of the most serious aspects of the presence of sulphur oxides in the atmosphere is their effect on human and animal health and, though the causation by them of respiratory diseases is still under discussion, there is no doubt that these pollutants will aggravate the conditions of sufferers from these complaints. This is proved by the steep rise in mortality and morbidity in severe fogs, and by the incidence of bronchitis, which in this country with its high sulphur contamination, is higher than anywhere else in the world.

Sulphur in Coal

The primary fuels, coal and petroleum, like all natural products, differ widely in composition and other properties according to their geological origin and geographical location. The sulphur content of British coal ranges from below 1 per cent to 3·6 per cent and over. The average may be taken as 1·6 per cent. This means that the total coal produced annually, say 200 million tons *contains* 3·2 million tons of sulphur. This is equivalent to nearly 10 million tons of sulphuric acid. As most of the sulphur is converted to sulphur dioxide and on further oxidation in moist air or on the ground to sulphuric acid or its compounds, the significance of this figure will be realized when it is compared with the commercial production of this acid the U.K. which in 1958 amounted to 2¼ million tons.

The sulphur content of coals has of late shown a definite tendency to rise. This is due partly to the gradual exhaustion of the higher quality seams and partly to modern methods of machine mining which cannot discriminate between good and bad quality as the manual collier could do. Furthermore, the relative proportions of low-sulphur, medium-sulphur and high-sulphur coals in the various regions of production bracketed in the above-mentioned range of sulphur percentages have undergone an unfavourable change. The proportion of very low-sulphur coals has dropped in the two decades 1938–1957 from 49 per cent to 34 per cent of the output (112–71 million tons) whilst that of very high-sulphur coals has trebled in the same period from 5 per cent to 15 per cent (12–30 million tons), the output having fallen from 227 million tons to 210 million tons.

Sulphur is a normal constituent of the vegetable raw material such as was transformed during geological periods into coal. Hence the resulting end product contains sulphur compounds that are in organic combination with the carbonaceous substances. It is the "organic" sulphur, indissolubly bound to the pure coal substance, which makes the whole sulphur problem so intractable.

British coals contain on average 0·8 per cent of organic sulphur, i.e. exactly one-half of the total. The other, inorganic half, is in the form of sulphidic minerals, mainly pyrites. They may be lumpy and intergrown with coal or finely disseminated throughout the mass.

Coal Preparation

In the present state of our knowledge it is not possible to extract organic sulphur direct from coal, but the percentage of inorganic sulphur can be lowered by well-known means, more or less readily, depending on the structure of any particular seam or type.

The necessity for "coal washing" began to be realized about the turn of this century, to comply with the demands of the iron and steel industry for a higher quality of metallurgical coke than was obtainable from raw coal. Raising the quality involved the extraction of ash-forming shale as well as sulphur minerals.

This "mechanical" coal preparation as distinct from the archaic, but still practised method of picking lumps of pyrites by hand from a moving belt, made only slow progress. By 1938 no more than 45 per cent of the output was mechanically cleaned with a steady rise since nationalization to over 60 per cent, but 17 per cent is still hand-picked.

The impurities in coal differ according to size of lump or particle. Sulphur—and ash—are concentrated in the "smalls" which logically should claim preferential treatment in the cleaning scheme. In fact the major portion of smalls is not subjected to cleaning treatment. Hence, the bulk of the accumulated coal stocks, now approaching 50 million tons, consists of such material to which beneficiation has not been applied.

Firing uncleaned smalls makes an unduly heavy contribution to air pollution. The largest coal consumer, the electricity generating industry (45 million tons in 1958) follows a policy of using this class of low quality coal of high and sometimes very high sulphur content. The reason is no doubt that its price ton for ton is low. Also, as an insurance against the uncertainty of the supply of fuel of better and more consistent quality, post-war power stations were designed to deal with the poorer material, taking the incubus of excessive ash and sulphur into the bargain. As a result, power stations discharge more than a million tons of sulphur dioxide a year into the atmosphere, more than any other class of industry.

Sulphur in Coke

Specifications for the chemical and physical properties of metallurgical coke suitable for modern iron and steel making have been tightened up in the course of years, and coke oven works must provide themselves with coal well enough cleaned—mostly in their own washeries—to keep sulphur in pig iron and steel at the required minimum.

The gas industry has no cleaning plants under its control, but depends for the quality of the supply of carbonizing coal entirely on the National Coal Board.

To comply with the provisions of the Clean Air Act, notably those relating to smoke control areas, much of the 19 million tons of unprocessed coal burned annually in open grates will have to be replaced by gas coke including a portion of the so-called premium fuels. Gas coke as at present supplied does not find favour with many householders. Although it fulfils the law's requirement of smokelessness, there are grave objections to its ash content which in part at least militates against ready ignition and fire maintenance. In order to overcome the public's reluctance to accept gas coke, the coal used in its manufacture should be much more drastically freed of its impurities.

Such cleaning will automatically reduce the content of sulphur which is particularly objectionable since its oxides are discharged from millions of chimneys at low level.

Washery Discard

Coal washing broadly involves the separation into clean coal and "dirt" possibly preceded by removal of fine dust. The dirt is discarded and tipped on spoil heaps, which disfigure the countryside by their unsightliness. This refuse consists of shale, much of it carbonaceous, some coal and pyrites. Many spoil heaps have been on fire for years emitting tarry and sulphurous fumes.

To halt the further extension of this nuisance the Clean Air Act makes a mine owner, i.e. the National Coal Board, guilty of an offence if he does not employ all practicable means for preventing the combustion of deposited refuse or the emission of smoke and fumes therefrom.

The loss of tonnage of material already mined and brought to the surface has, quite naturally, always lent support on economic grounds to the coal industry's objection to thorough cleaning. But it should be realized that the refuse accruing at the rate of 40 million tons a year will be equivalent in potential heat value to 10 million tons of "saleable" coal. By allowing more "middlings" to go into the refuse and thus aisring its calorific value, this material could be burned under controlled conditions, as is done on the Continent in plant designed for the purpose. Thus on the one hand, much cleaner coal could be obtained for gas coke making and on the other the more concentrated sulphur oxide content of the combustion gases could be more readily made amenable to treatment and the incombustible residue left would be inocuous in the spoil bank.

Admittedly, colliery refuse is a very poor raw material for acid manufacture, but it is available free of charge and the higher plant and operating costs involved should be set against the value of imported brimstone and pyrites which in 1958, a low-cost year, amounted to £5·05 millions.

Sulphur in Petroleum

As in coal, the sulphur content of petroleum varies widely according to its origin from 0·05 per cent for some Pennsylvanian to 5 per cent for certain Texas crudes. Crude oil from Kuwait, the largest supplier to the U.K. contains 2·6 per cent and crude from Iraq, the second largest, 2·2 per cent sulphur. Taking a mean of 2·5 per cent the sulphur in the 34 million tons of crude oil imported into this country in 1958 is of the order of 850,000 tons. The great bulk of the products from this crude is used as fuel. The distillates, motor spirit, kerosine, diesel and gas oil, are refined by extracting more or less sulphur compounds or, of late, actually elemental sulphur, from them, but about 70 per cent of the sulphur is concentrated in the distillation residue which amounts to 20 or 30 per cent of the feed stock. This residue is burned as liquid fuel. The discharge of more than a million tons of sulphur dioxide liberated from it poses a serious air pollution problem, made more acute by the rapidly expanding usage of oil fuel and the steadily rising sulphur content of crude oil supplies.

The obvious initial step in removing the pollution of the atmosphere by sulphur oxides is to remove as much sulphur as possible at the points of fuel production, the collieries and the oil refineries. This is done with coal to a certain but inadequate extent. Likewise, removal of sulphur from petroleum has so far been limited to lighter, distilled products. Results of researches into methods for extending this practice to heavy fuel oils are, for commercial reasons, not widely published. The modern catalytic cracking processes should manifestly be amenable to sulphur elimination.

The liberation of hydrogen and gaseous hydrocarbons inherent in these processes presents the opportunity for hydro-desulphurization by which sulphuretted hydrogen is formed, a gas from which elemental sulphur has been made for many years.

Responsibility for Sulphur Pollution

The relative responsibility of fuel purveyors may be summarized as follows:

Coal, in spite of contraction of demand, is still and will remain for long our principal primary fuel. Nearly all the sulphur in it for whatever purpose the fuel is utilized will find its way into the air with the exception of a small proportion left in the ashes. Much of the sulphur could be eliminated at the source by the application of more extensive and more thorough cleaning.

The energy provided by the electricity supply industry for power, heating and lighting does not contribute to air pollution of any kind, but the generating partner of that industry which will soon consume one quarter of the output of the mines, is responsible for the emission of sulphur oxides in high concentration rom relatively few point sources.

The gas industry, bound by statute, extracts nearly all sulphur from raw gas in form of marketable spent oxide, but it is still faced with the problem of corrosion of consumers' appliances by the residual "organic" sulphur.

The industry's solid product, gas coke, of necessity emits sulphur oxides on combustion. In that respect it depends on the degree of cleaning applied to gas coal by the National Coal Board. In total gasification now being introduced, all sulphur is converted to sulphuretted hydrogen which can be treated on conventional lines for conversion into elemental sulphur.

The coking industry is obliged to clean the coal it turns into metallurgical coke so as to meet with the demands for sulphur-free iron and steel. Some of the sulphur remaining in the coke is recoverable from blast furnace gases, but will get into the atmosphere if burned without such treatment.

There is little hope for a diminution of sulphur emission by general industry. Large manufacturing units may have to take certain measures on account of their size or for the protection of their own plant or products, but small or medium sized factories can do little more than press for the supply of low-sulphur fuels.

There remains the householder, flat and office buildings and "institutions." They are entirely in the hands of the suppliers of fuels and cannot avoid sulphur pollution if they are using solid—whether smokeless or not—or liquid fuels.

Remedies

The Electricity Commissioners, in the early 1930s, gave their consent for the building of power stations in inner London only on condition that sulphur oxides should be scrubbed out from the flue gases. The system installed in Battersea uses large quantities of Thames water for washing the gases, returning the effluent to the river.

A modified Battersea process is in operation on the oil-fired Bankside station. The extension of the existing station to the full designed capacity is now in course of construction, the old obsolete one on the same site and not fitted with flue gas treatment having been demolished.

In the Fulham station a non-effluent process was used, in which the acid in the gas was neutralized with chalk, devised to yield calcium sulphate (gypsum) of reasonable purity. The Fulham plant was of high efficiency, but was shut down during the war for security reasons and not restarted.

A process investigated during the last twenty years is now in operation in a pilot plant in Nottingham. It uses ammonia liquor for neutralization and yields ammonium sulphate and some subsidiary by-products including sulphur.

All these processes succeed in preventing flue gas sulphur from being emitted into the atmosphere. Their main characteristics may be summarized as follows:

The Battersea/Bankside method depends on the capacity of a large river to keep the reaction product in solution. After the completion of Bankside saturation of the Thames will be reached. There is no other river in the country with an adequate flow to allow air pollutants to be discharged into it without further impairing the purity of the water. River Boards understandably dislike to see the air being cleansed and their water courses used as a sink for the contaminating material.

The Fulham process requires an adequate supply of chalk or lime which is obtainable in many districts. Its product, calcium sulphate, is wanted as an additive to cement. It is finding a use in agriculture, notably in Sweden, Holland and America.

The ammonia process is restricted by the amount of this neutralizing agent available from the gas and coking industry and synthetic ammonia plants.

So, all the washing processes have their limitations. The objections raised to flue gas washing on the score of cooling the gases and thereby lowering their buoyancy can only be accepted if the washing is not adequate and the descending plumes still contain appreciable amounts of acid.

From the foregoing it becomes manifest that the real need is for intensive research coupled with inventiveness to evolve a system for the dry removal of sulphur from the combustion products of power stations which, due to the magnitude of their operations, are the only fuel users to whom such methods could and should be applied.

Sulphur Economics

All the parties concerned in the supply and large-scale consumption of fuels express and show their sincere willingness to help in the great work of keeping the air clean, but plead excessive cost to them and their customers as the reason for their inability to do enough. Reliable detailed estimates of the cost of carrying out these reforms if ever made, have never been made public. Whatever the result of such calculations it will be found that the cost will be within that of the damage done.

The Beaver Committee judged that the nation pays for air pollution in direct costs and loss of efficiency £250 million a year, not counting the cost of fuel wasted, and without including damage to health of man and beast, much of which is due to sulphur acids. This estimate is already considered to be too low.

There will be a certain return on the credit side from sulphur recovered, particularly from petroleum products and spent oxide. In order to assess the value of this realistically the world demand and production of sulphur must be considered. After the shortage in 1951, followed by a rise in production and then a drop in demand due to the trade recession in America, the consumption of sulphur in 1958 was 7½ million tons. Some old sulphur domes may be nearing the end of their economic life, but new sources are being developed, such as those of native (Frasch) sulphur in Mexico and the Freeport off-shore plant at Grand Island. The new natural gas field at Lacq in France has begun extraction of sulphuretted hydrogen and its conversion to sulphur, with a projected annual output of $1\frac{1}{4}$ million tons.

It is estimated that world demand for sulphur in five years time will be more than 10 million tons a year. The steady growth of the chemical industry will absorb increasing supplies of sulphur and its compounds. To raise food for the populations of under-developed countries enormous quantities of fertilizers will be needed, mainly superphosphate and ammonium sulphate, all depending on sulphuric acid for their manufacture.

A close study of all these economic factors is urgently called for.

The Clean Air Act has put the country well on the way to clear the air of its visible impurities. The next step should be the purging of the atmosphere of its invisible and insidious poisons.

III. 36

DIESEL-OIL COMBUSTION PRODUCTS: EFFECTS OF IGNITION PROMOTING ADDITIVES ON NITROGEN OXIDES AND CARBON MONOXIDE CONTENT

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SUMMARY: This paper gives the results of a series of experiments on the effects of an organic nitrate base additive on the nitrogen oxide and carbon monoxide content of diesel exhaust gases. The additive was shown to influence the nitrogen oxide content only when running at minimum speeds. The tests performed also showed that nitrate base additives are particularly efficient in eliminating carbon monoxide when low cetane number gas-oils are used, especially if the engine runs at high load. When the fuel oil ignition properties are such as to meet engine demand, the use of these additives is more or less superfluous.

Introduction

The composition of exhaust gases is currently a subject of extensive investigation, for these gases play a major role in air pollution. It is therefore desirable for wider knowledge to be acquired on the relation between this composition and the characteristics of fuels used.

Since ignition promoting additives can be used with diesel oils, it has occurred to us that a useful purpose would be served by determining to what extent the presence of such additives can influence exhaust gas composition.

In this note the results are submitted of a first series of experiments performed in our laboratories on the effects of an organic nitrate base additive on the nitrogen oxides and carbon monoxide content of exhaust gases.

Our attention was focused on the nitrogen oxides content because of the fact that ignition promoting additives, in that they modify combustion patterns, indirectly influence the quantity of these oxides in exhaust gases.

The influence of these additives from the angle of their being a chemical source of nitrogen oxides, instead, is quite negligible, since they are used in extremely low quantities.

The ignition promoter used was an amyl nitrate base product marketed as D.B.36, and referred to in our note as A.N.

Research on the influence of additions of this and other promoters on the ignition properties of various gas-oils has been reported on in a previous paper.[1]

Two gas-oils with a widely different chemical composition were used as fuel: a paraffinic, relatively high cetane number gas-oil and a naphthenic, low cetane number gas-oil.

The specifications of these gas-oils "with," and without the additive, are given in Table I.

Tests were performed with a C.F.R. F.5 engine coupled to a General Electric electrical dynamometer brake. The engine was equipped with a model EC.1 Solartron electronic ignition advance and delay detector.

The C.F.R. F.5 is a pre-chamber diesel engine, offering a wide range of adjustment and control of the compression ratio, advance, pump delivery, injector, water and oil temperature, and suction air.

Table I

	Paraffinic	*Naphthenic-aromatic*
Clear C.N.	53·0	35·0
C.N.+0·25 A.N. per cent ...	62·0	40·5
C.N.+1·0 A.N. per cent ...	73·0 (extrap)	46·5
C.N.+2·5 A.N. per cent ...	—	57·5
Diesel (index)	54·5	38·8
Specific gravity at 15°C. ...	0·845	0·876
Aniline point °C.	66·6	54·0
Distillation: start	202°C	220°C
	per cent	per cent
Vol. distilled at 225° ...	5	—
,, ,, 250° ...	22	16
,, ,, 275° ...	49	58
,, ,, 300° ...	69	82
,, ,, 325° ...	83·5	—
,, ,, 350° ...	92·5	94
End point	—	342°C
Total distillate	—	97·5
	Per cent	Per cent
Residue	7·5	2·5
Sulphur	0·92	0·73
Conradson residue	0·19	0·27
Corrosion test	1·2	1·2

The operation conditions, which were unvaried throughout all the tests, are given in Table II.

Table II

Cooling water temperature	100°C
Injector temperature	38°C
Aspirated air temperature	66°C
Oil temperature	50°C
Compression ratio	13:0

The exhaust gas nitrogen oxide content was assayed by the phenoldisulphonic acid method described in a previous note.[2]

The nitrogen oxides formed by reaction of oxygen with nitrogen and hence contained in the exhaust gas may be the following: NO nitric oxide, N_2O_3 nitrous anhydride, NO_2 nitrogen dioxide, N_2O_4 nitrogen tetroxide.

NO, N_2O_3 and NO_2 are so closely related that these oxides are rarely considered separately.

NO oxidates rapidly in the presence of O_2 to NO_2; N_2O_3 in the gaseous state is almost completely dissociated into NO and NO_2, nitrogen dioxide dissolves in cold water forming equal parts of HNO_3 and HNO_2.

Since the absorbing solution used in the phenoldisulphonic acid method contains an oxidant (H_2O_2) all the nitrogen oxides contained in the exhaust gas are assayed in the form of nitric acid. These oxides are then expressed as NO_2 in p.p.m.

The samples are drawn off into bottles or flasks through a stainless steel valve located in the end of the flexible exhaust pipe.

Although somewhat laborious, this method of determination gave satisfactory results.

In addition to the nitrogen oxide content, assays were made with Orsat's apparatus of the CO_2, CO and O_2 content of exhaust gas in order to provide a more comprehensive general picture of its composition.

Influence of engine conditions, gas-oil specification and presence of additives on the nitrogen oxide content. Influence of the fuel/air ration (F/A).

The first set of tests was made to study changes in the exhaust gas nitrogen oxide content with the engine running on clear gas-oil and varying fuel/air ratios. The engine was kept constantly at a speed of 900 r.p.m. while the output varied with the fuel/air ratio from minimum to maximum.

These running conditions with constant speed and variable fuel/air ratio are fairly close to actual diesel engine service conditions, which unlike petrol engines, operate with widely varying load over a fairly narrow range of speeds.

In Arabian gas-oil (see Fig. 1) the nitrogen oxides content rose quite appreciably with higher fuel/air ratios until it reached a maximum. A further rise in the fuel/air ratio to values tallying with maximum output, instead, brings about a rapid decline in the nitrogen oxide content.

With aromatic gas-oil (see Fig. 1) there is likewise a very considerable change, of similar pattern, in the nitrogen oxide content at varying fuel/air ratios. In this latter case, however, the curve could not be completed because of low fuel/air ratios (and at 900 r.p.m.) the bad ignition quality of the gas-oil under test no longer allowed the engine to run properly at the compression ratio previously fixed.

The pattern of these curves can be explained in the light of the fact that the formation of nitrogen oxides is generally facilitated by high temperatures and excess oxygen, and that it always depends on the conditions under which the gas-oil combustion takes place (combustion temperature and pressure, fuel/air ratio, ignition delay, etc.).

The conditions most propitious to the formation of nitrogen oxide rarely occur simultaneously: when (in idling conditions) the low fuel/air ratio results in considerable quantities of oxygen, but since the temperature is fairly low (see Table III) it does not suffice for complete combustion.

Table III
Mean prechamber temperature

	Fuel/air	*r.p.m.*	*Temp. °C*
ARABIAN GAS-OIL			
Clear	0·027	600	405
	0·073	900	685
+1 per cent A.N. ...	0·027	600	405
	0·026	740	450
	0·068	900	695
VENEZUELAN GAS-OIL			
Clear	0·032	600	380
	0·074	900	630
+1 per cent A.N. ...	0·031	600	410
	0·030	690	430
	0·074	900	685

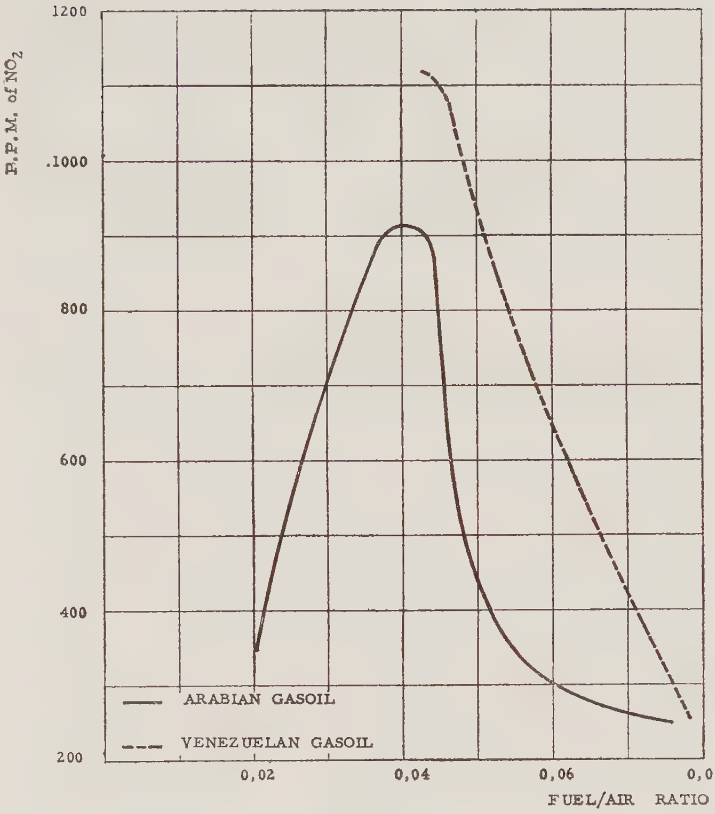

Fig. 1

With heavy loads the engine temperature increases notably (see Table III) but the fuel/air ratio has likewise increased and a gas analysis reveals a minimum quantity of oxygen while a certain amount of carbon monoxide and free carbon can already be noted. These conditions are unpropitious to the formation of N_2 oxides.

The best conditions are intermediate, as shown by the test results given in Fig. 1.

Effect of additives.—In the light of the foregoing conclusions on variations in the nitrogen oxide content depending on engine running condition variables, the second set of tests was devoted to investigating the quantity of nitrogen oxides in relation with the chemical composition of the gas-oil used and whether or not it contained organic nitrate base additives as ignition promotors.

The tests were performed mainly at three different speeds, 600, 900 and 1,150 r.p.m. with all other conditions constant for all three speeds except the load which, at the same fuel/air ratio, varied with the type of gas-oil used.

The first set of tests, taken with the results of some other preliminary trials, had shown that running at a constant load would have meant that for the same engine speed, the fuel/air ratio would have had to be different for each type of gas-oil; among other things it had emerged that even slight variations in the fuel/air ratio caused more appreciable changes in the exhaust gas composition than those engendered by keeping the fuel/air ratio unvaried and at the same time allowing slight output changes.

Tests were also made with larger quantities of additive than those habitually employed in order to study their effect better.

The analysis data of these reports are recapitulated in Tables IV and V. They refer to two clear gas-oils with additive content of 0·25–1·0—2·5 per cent. The figures given in those tables were corroborated by repeating the tests several times.

The deductions that can be made from Tables IV and V are: (1) With paraffinic gas-oil, the nitrogen oxide content at 600 r.p.m. and fuel/air ratio or about 0·026 at idling, rises as the quantity of additive increases, from values around 375 p.p.m. to about 490 p.p.m.

At 900 r.p.m. with a fuel/air ratio of about 0·067 with maximum load, the nitrogen oxide content remains more or less constant, at increasing additive quantities, around values between 330 and 370 p.p.m.

Table IV
Nitrogen Oxides Content (p.p.m. of NO_2) with Arabian Gas-Oil

Speed r.p.m.	600	900	1,150
Fuel/air ratio	0·026	0·067	0·067
Clear gas-oil C.N. 53·0	375	354	405
Gas-oil 0·25% A.N. ...	377	331	392
Gas-oil 1·0% A.N. C.N. 73·0	478	347	407
Gas-oil 2·5% A.N. C.N.	484	368	398

Table V
Nitrogen Oxides Content (p.p.m. of NO_2) with Venezuelan Gas-oil

Speed r.p.m.	600	900	1,150
Fuel/air ratio	0·030	0·074	0·074
Clear gas-oil C.N. 35·0	130	345	368
Gas-oil 0·25% A.N. C.N. 40·0	177	350	282
Gas-oil 1·0% A.N. C.N. 46·5	234	325	228
Gas-oil 2·5% A.N. C.N. 57·5	405	291	337

The same statement applies to the tests at 1,150 r.p.m. with a fuel/air ratio of 0·067, where the content ranges from about 390 to 410 p.p.m.

(2) With aromatic gas-oil at a minimum of 600 r.p.m. and fuel/air ratio of 0·030, there is still a decided upward trend in the nitrogen oxide content as the additive content rises. However, the figures are always lower than in the case of paraffinic gas-oil and fluctuate between 130 p.p.m. and 405 p.p.m. This is due to the bad ignition properties of aromatic gas-oil which are particularly troublesome at minimum speeds.

With maximum load at 900 r.p.m. and a fuel/air ratio of 0·074 the nitrogen oxide content tends to remain constant, with fluctuations between 290 and 350 p.p.m.

A similar trend was found in maximum load tests at 1,150 r.p.m. with fuel/air ratio of 0·074, the quantities fluctuating between 280 and 370 p.p.m.

Generally speaking, the effect of the additive content on nitrogen oxide content is apparent with both gas-oils when running at minimum speed. It is, indeed, only under these conditions that rising quantities of additive are accompanied by higher nitrogen oxide content: this fact can be explained, since the presence of the additive diminishes the ignition delay and upgrades fuel efficiency, hence the presence of excess oxygen leads to higher temperatures.

At high loads, when engine running conditions are already in themselves more favourable to combustion, the effect of the additive on the NO_2 content is practically negligible. The quantities found are always below the maximum contents noted at minimum load (600 r.p.m.) evidently because the smaller amount of free oxygen (richer mixture) and perhaps the shorter combustion time are of influence.

The aromatic gas-oil test results could not be repeated as satisfactorily as those made on the paraffinic gas-oil.

Actually the engine running conditions, suitable for paraffinic gas-oil tests, were in many cases not such as to allow proper running on aromatic fuel and consequently the nitrogen oxide content appears low because of low combustion temperature (see Table III) and, in some cases, because of missing strokes (misfiring).

Table III gives the combustion temperatures, which show that for naphthenic gas-oil, with or without additive, temperatures tend to be lower than those recorded with the paraffinic oil. This difference is especially evident at minimum speeds and as already remarked, the relative nitrogen oxide contents noted with aromatic gas-oil are notably below those noted with paraffinic gas-oil.

Effect of additives on the exhaust gas carbon oxide content

These tests were performed at 900 r.p.m., the fuel/air ratios being close to those for maximum output. Actually, while at low engine loads (idling) incomplete combustion is usually characterized by unburned or by oxidized hydrocarbons (whitish-blue fumes), when the engine is running at top speed incomplete combustion is characterized by CO and free carbon (black fumes) as well as traces of unburned hydrocarbons.

Additives have a very weak effect on Arabian gas-oil.

At maximum load, with the engine turning over at 900 r.p.m. and a constant fuel/air ratio of about 0·068, giving a practically correct mixture, a 0·25 per cent additive content is not successful in eliminating the presence of CO (see Table VI).

If the fuel/air ratio is somewhat reduced to about 0·065 at 900 r.p.m. with the same output, the CO content in clear gas-oil already drops to practically nil (see Table VI).

If the fuel/air ratio is raised to about 0·071 to foster the formation of CO and control the effect of the additive on its reduction, then the CO content can only be reduced by employing fairly high quantities of additive (see Table VI).

The same thing happens with aromatic gas-oil.

If the fuel/air ratio is maintained constantly at about 0·074, even high quantities of additive have little influence on the elimination of CO (see Table VII).

When the fuel/air ratio is slightly lowered to values in the neighbourhood of from 0·070 to 0·072 at which output remains practically unvaried, carbon monoxide is reduced by the additive, but only slightly (see Table VII).

It is known that ignition property promoting additives have their effect by reducing the ignition delay with an ensuing increase in output; the presence of the additive in the gas-oil therefore sums up to the

Table VI

Effect of Additive (A.N.) on the Exhaust Gas Composition (at maximum load—900 r.p.m.—Arabian Gas-oil) with F/A Ratio Constant

	CO_2 *per cent*	O_2 *per cent*	CO *per cent*
F/A ratio 0·068			
Clear gas-oil ...	13·1	0·4	0·7
Gas-oil+0·25 per cent A.N.	12·0	0·4	1·0
F/A RATIO 0·065			
Clear gas-oil ...	12·8	1·0	0·1
Gas-oil+0·25 per cent A.N.	12·5	1·0	0·1
F/A RATIO 0·071			
Clear Gas-oil ...	12·4	0·5	2·9
Gas-oil+0·25 per cent A.N.	12·4	0·0	3·2
Gas-oil+1·0 per cent A.N.	12·0	0·4	1·8
Gas-oil+2·5 per cent A.N.	12·8	0·2	0·9

possibility of reducing the fuel/air ratio, while maintaining unchanged output, to foster CO elimination, as has been seen in the foregoing.

Table VII

Effect of Additive (A.N.) on the Exhaust Gas Composition (at Maximum Load—900 r.p.m.—Venezuelan Gas-oil) with F/A Ratio Constant

	CO_2 *per cent*	O_2 *per cent*	CO *per cent*
F/A RATIO 0·074			
Clear Gas-oil ...	10·8	0·0	3·0
Gas-oil+0·25 per cent A.N.	12·5	0·0	2·6
Gas-oil+1·0 per cent A.N.	12·1	0·0	2·8
Gas-oil+2·5 per cent A.N.	11·3	0·0	2·9
F/A RATIO 0·070–0·072			
Clear gas-oil ...	13·6	0·3	2·1
Gas-oil+0·25 per cent A.N.	13·7	0·4	1·9
Gas-oil+1·0 per cent A.N.	13·8	0·3	1·4
Gas-oil+2·5 per cent A.N.	14·0	0·3	1·5

It can thus be concluded that the action the additive has on the carbon monoxide content occurs in two ways: (1) directly—improving the combustion efficiency; (2) indirectly in that for the same output it allows using a lower fuel/air ratio.

When both of these effects are exploited the drop in CO is appreciable.

This is proved by the figures given in Table VIII giving some typical exhaust gas analyses for minimum and maximum running conditions with both gas-oils.

In observing the figures shown in this table for tests at 900 r.p.m. where the fuel/air ratio has been lowered with the changeover from clear to additive gas-oil but at the same output, it can be seen how this reduction, made possible by the presence of the additive, permits considerable reduction in the CO content.

Table VIII

Effect of Additive (A.N.) on the Exhaust Gas Composition (at Maximum Load—900 r.p.m.) with F/A Ratio Changed

Gas-oil	CO_2 *per cent*	O_2 *per cent*	CO *per cent*	NO_2 *p.p.m.*
ARABIAN				
Clear—F/A ratio 0·096	12·1	0·7	2·4	345
+0·25 per cent A.N.—F/A ratio 0·067	12·4	1·4	0·7	331
VENEZUELAN				
Clear—F/A ratio 0·074	11·0	0·6	4·4	345
+0·25 per cent A.N.—F/A ratio 0·070	12·6	0·8	1·7	350

It is also interesting to note from Table VIII that with aromatic gas-oil the additive has more noticeable effects because this fuel has poorer ignition properties.

Indeed, there is a special call for additives in those low cetane number gas-oils which demand high fuel/air ratios to give maximum output, and thus produce high CO exhaust gas. The nitrogen oxide content under these conditions does not, evidently, change much.

Conclusion

Certain quantities of nitrogen oxides in diesel engine exhaust gases depend both on the gas-oil characteristics and on the engine combustion conditions (combustion temperature, fuel/air ratio, etc.).

With all the gas-oils (clear and with additive) used for the tests described, the highest content of the above oxides was found when running at intermediate loads.

The additive was shown to influence the nitrogen oxide content only when running at minimum speeds.

The tests performed also showed that nitrate base additives are particularly efficient in eliminating carbon monoxide when low cetane number gas-oils are used, especially if the engine is run at high load. When the fuel oil ignition properties are such as to meet engine demand, the use of these additives is more or less superfluous.

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PERFECT COMBUSTION: ESSENTIAL CONDITION FOR REDUCING AIR POLLUTION

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SUMMARY: The paper discusses the requirements for smoke-free combustion in an oil-fired boiler unit. The results of a series of tests are described. A new form of refractory system is described which, being of lighter construction, increases the speed with which the combustion chamber reaches working temperature.

Air pollution, as an air contamination of a certain degree of concentration may be considered an uninterrupted phenomenon which, however, under particular conditions, such as increasing effluents due to various combustion processes (heating installations, diesel road cars, industries) becomes the very well known universal phenomenon of smog.

A very interesting investigation has been carried out by the Air Pollution Research Centre of Milan regarding this matter. The purpose of the investigation was to determine the different values of air pollution of the Milan area during the winter and summer seasons. The results obtained demonstrated how much the level of air pollution is due to heating installations. Indeed, unvaried air pollution values being provided by industries and road vehicles' effluents, the balance between winter and summer air pollution (2/1) is the quota due to the heating equipment. Such a quota represents the prevalent reason for winter air pollution, while it may be said that it is the most unpleasant aspect of air pollution, as it is composed of dirtying substances.

This paper " Perfect combustion, essential condition for reducing air pollution ", mainly refers to the phenomena involving combustion residuals and soot coming from chimneys (carbon monoxide and cracking products).

It is indeed well known that air pollution in this field is mainly due to cracking products coming from chimneys more than SO_2 effluents which residuals, on the other hand, are easily dissipated in the air. Dark smoke and soot flowing from heating equipment are, we can say, the most important factors causing air pollution and even more if we consider they may absorb sulphur dioxide and other harmful and vexatious substances which may be inhaled.

Air pollution in this field may be caused by solid or liquid fuel and is mainly due to irrational design, bad operation of heating equipment or not using proper fuel. It is important, in any case, to note that on fuel oil heating equipment soot emission is not so very important as for heating equipment using solid fuel.

This is evident if we consider that, independently from agglomeration and condensation phenomena, the small particles of soot produced bv fuel oil combustion, have a size of approximately $\frac{1}{5}$ if compared with the fuel drops. While, on the other hand, particles of soot produced by solid combustibles reach a size of $\frac{1}{8}$ to $\frac{1}{4}$ of an inch.

Through the analysis of the main factors of combustion phenomena (fuel temperature, atomization degree, combustion degree of atomized fuel, air combustion time, combustion chamber temperature), results show that the most important factors to be considered are the fuel atomization degree and combustion chamber walls temperature.

Indeed, it is well known, that soot is originated by cracking distillation phenomena to which fuel is submitted during the oxidation process.

Oil particles derived by the atomization process of the fuel oil burner run through a trajectory, having a different inclination, inside the combustion chamber; during such a trajectory, the small fuel drop is submitted to the oxidation process, which is as fast and complete the smaller it is and the higher the combustion chamber temperature.

If these two conditions are not accomplished the small fuel drop flows out of the combustion cone formed by the burner and through a cracking distillation process becomes a carbon residual.

It is also important to consider the fact that in these processes sulphur trioxide and steam act as agglomeration and condensation centres.

The elimination of the steam is not possible as it is an essential part of combustion gas while the sulphur trioxide is only an " occasional " component as it depends on the particular structural characteristics of the combustion chamber.

Such a compound is formed inside the combustion chamber owing to catalytic oxidation of sulphur dioxide; catalytic agents in this case are the metal boiler surface and the combustion temperature. It is formed in small quantities (0·002–0·005 per cent of combustion gas), sufficient however to raise the smoke dew point, that is, to create a soot agglomeration centre. Through a proper adjustment of the above-mentioned factors a remedy to such inconvenience may be reached. Good atomization and a sufficiently high temperature of the combustion chamber walls are generally factors able to limit the above-mentioned phenomena.

Other elements like a properly shaped combustion chamber as well as a proper chimney draught offer the engineer a solution.

What is above mentioned has been confirmed by experience, and practical tests on installations made during the period covering the past ten years of activity as well as by the results obtained from industrial and domestic heating equipment.

Regarding this, the attention of the reader is called to a set of experimental tests carried out in a heating installation located in a Riello plant—Legnago (Italy). Such tests were carried out with a view to indicating how important it is to have a proper adjustment of the above-mentioned combustion factors especially concerning soot formation.

The first set of experimental tests was made on a heating installation plant including a warm water boiler (normal rating 948,000 B.T.U. per/hr) with combustion chamber protected by normal refractory bricks sealed with refractory concrete.

The installation was operated with an automatic fuel oil burner (Riello type C2P). The chimney had the following size: height 26 ft, rectangular section 1 ft 4 in × 2 ft.

The natural chimney draft had been augmented by an electric automatic blower, set to operate when the burner started and turn off as flame brightness showed perfect combustion.

The data on oil-fuel used are as follows:

Fuel oil viscosity 12°E at 122°F;
Density 19,03 A.P.I.;

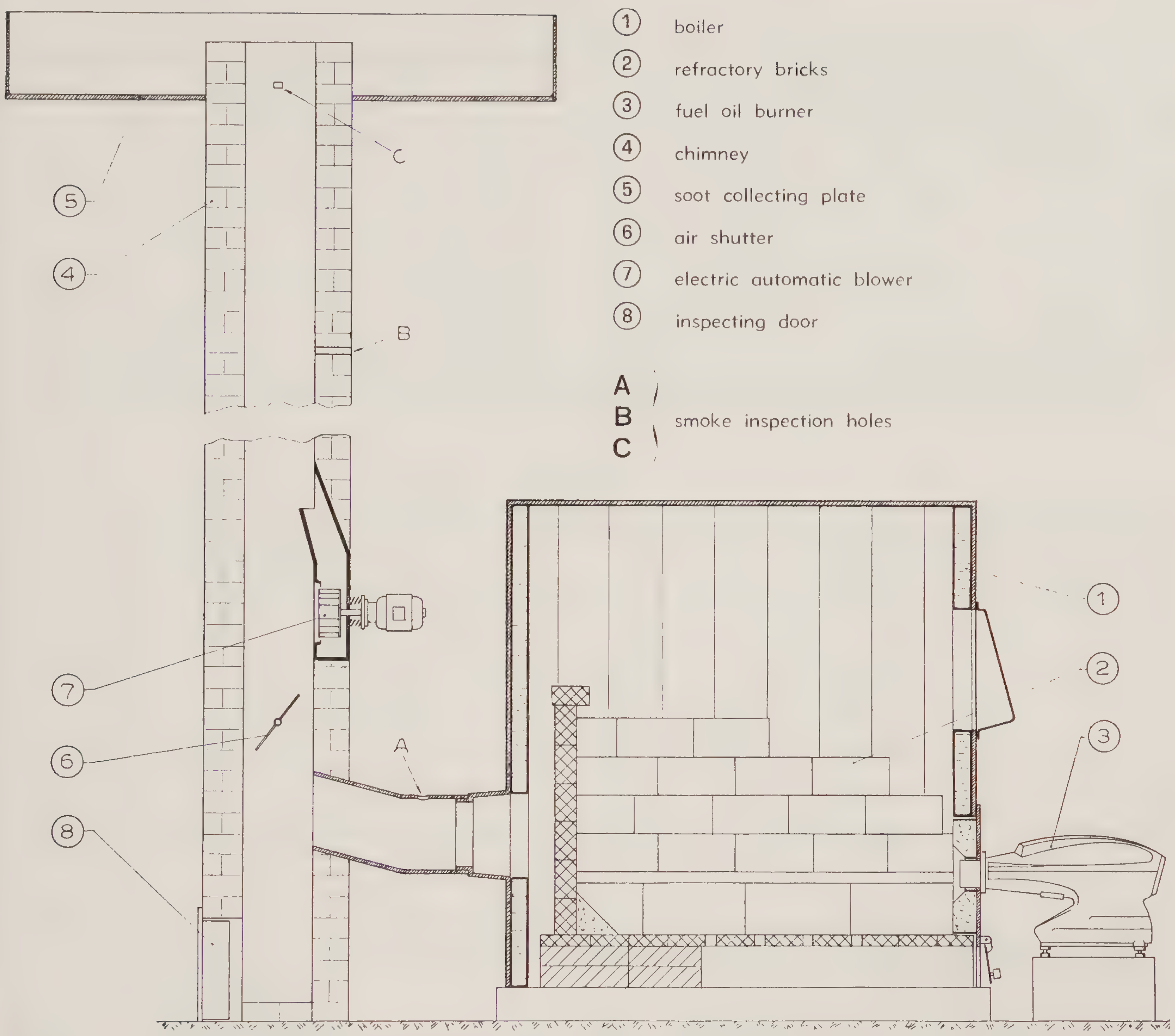

Fig. 1 - Experimental heating installation

Low heat content (about 164,500 B.T.U./Imp. gal.);
Sulphur 3·2 o/o;
Preheating temperature 158°F;
Fuel oil consumption 6·7 gal per hr;

Tests have been carried out to determine the following variables:

(a) combustion gas temperature;
(b) carbon dioxide content (percentage);
(c) water temperature in the boiler.

The determination of combustion gas has been carried out to obtain reference data about the possibility of formation of condensation centres inside the chimney so three pairs of electric thermocouples were placed at points (a), (b), (c) (see Fig. 1).

Measurements of carbon dioxide have been taken as indication of combustion efficiency, for this purpose an ORSAT apparatus (absorbing type) has been employed with 3N of KOH.

The water temperature in the boiler has been taken within the limits indicated for each set of experimental tests, turning on and off the fuel oil burner by controlling thermostats.

The soot quantity has been referred to the fuel quantity consumed in one hour so as to make results obtained, as far as possible, independent from oil burner operation periods. To make calculations easier figures have been multiplied by 10^4. Soot collection has been made as specified:

At chimney top there had been installed a plate having raised sides, the diameter of which plate was about 17 ft (see Fig. 1). Collection of soot was periodically made, dried in a stove at 230°F, then directly weighed.

The use of an air cleaner has not been considered in this paper as it is outside the subject examined, which has been limited to the study of soot elimination at its source.

Experimental tests have been carried out only under favourable meteorological conditions (no wind, no rain, temperature over 32°F).

Before each set of tests took place the chimney and boiler were carefully cleaned.

In the first set of experimental tests, combustion was controlled so that there was no visible smoke at the chimney-top. Table 1 reports the results obtained.

TABLE 1

Tests	Smoke temperatures (°F)			CO_2			Water temp. in the boiler (°F)	$\frac{\text{Soot weight} \times 10^4}{\text{fuel weight}}$
	A	B	C	A	B	C		
1st	464	450	383	9·1	7·8	4·6	140–158	17·0
2nd	446	430	370	8·5	6·8	4·5	140–158	18·5
3rd	455	437	374	9·2	7·2	4·8	140–158	15·2 Media = 16·9

Note.—Data refer to experimental tests lasting 24 hours. The same have been carried out during favourable meteorological conditions (no wind, no rain, temperature over 32°F).

TABLE 2

Tests	Smoke temperatures (°F)			CO_2			Water temp. in the boiler (°F)	$\frac{\text{Soot weight} \times 10^4}{\text{fuel weight}}$
	A	B	C	A	B	C		
1st	475	462	389	9·2	7·3	4·5	158–185	16·4
2nd	484	467	392	9	7·2	4·5	158–185	13·8
3rd	476	461	392	9·5	7·3	4·6	158–185	15·1 Media = 15·1

Note.—An increase in soot particle diameter has been noted.

Taking into consideration such a result, to reduce the range of the effects the water temperature in the boiler was from 140° to 158°F as minimum.

For this purpose the thermostats were varied on the supposition that smoke flow was partially due to an incomplete combustion of fuel oil particles contacting the insufficiently heated boiler walls.

Keeping unvaried all other characteristics of the installation the results obtained by a second set of experimental tests are those reported in Table 2.

From such a result may be noted a new slight reduction of the phenomena sufficient however to demonstrate that the way followed was the right one for coming very near to the solution of the problem.

So new experimental tests were carried out by further raising the temperature of walls where the drops, coming from the atomization cone, fell down.

The traditional refractory bricks have been removed and newly designed refractory bricks have been installed (Figs. 2 and 3). The high quantity of refractory material required in the traditional installation reduces the useful heated surface of the boiler and its high thermal inertia makes the boiler wall heating very slow. Consequently at the starting of operation, combustion conditions are not the best so by introducing a refractory system having a reduced thermal inertia, most inconveniences may be avoided.

This new refractory system manufactured by Messrs. Riello (Fig. 4) has a very light iron frame of prefabricated elements of standard size suitable to any type of heating boiler, supporting refractory bricks half-inch thick which do not require any kind of cement or concrete.

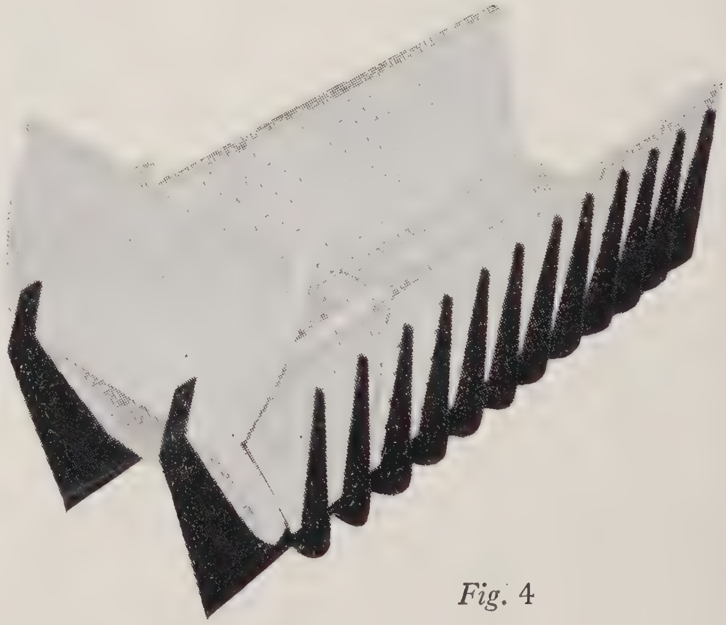

Fig. 4

These special bricks present many holes of conical section which increase the radiating power of the system.

This solution, it is easy to see, is very different from the traditional installation, and makes it possible to obtain a quick heating of the combustion chamber, so that an ideal combustion condition is reached since operation of the oil burner begins with noticeable reduction of soot. The results obtained during this experimental test are reported in Table 3.

The comparison of the results obtained from the

TABLE 3

Tests	*Smoke temperatures (°F)*			*CO_2*			*Water temp. in the boiler (°F)*	*Soot weight × 10^4 / fuel weight*
	A	*B*	*C*	*A*	*B*	*C*		
1st	500	469	410	9·5	7·4	4·8	158–185	8·1
2nd	507	479	401	10	7·6	5	158–185	9·8
3rd	488	473	395	10·1	7·6	4·8	158–185	7·5 Media = 8·8

Note.—Results show a reduction in diameter of soot particles compared with previous tests.

TABLE 4

Tests	*Smoke temperatures (°F)*			*CO_2*			*Water temp. in the boiler (°F)*	*Soot weight × 10^4 / fuel weight*
	A	*B*	*C*	*A*	*B*	*C*		
1st	545	502	416	11·4	8·6	5·5	158–185	2·5
2nd	561	509	422	11·5	9	5·6	158–185	—
3rd	556	509	420	11·8	9	5·8	158–185	0·5
4th	539	500	412	11	8·5	5·4	158–185	—
5th	582	523	431	11·6	8·6	5·6	158–185	1·0 Media = 0·8

Note.—To obtain an improvement of combustion conditions (thus maintaining smokeless operation), chimney draught has been controlled by an automatic air shutter. To make measurements possible the test time has been doubled.

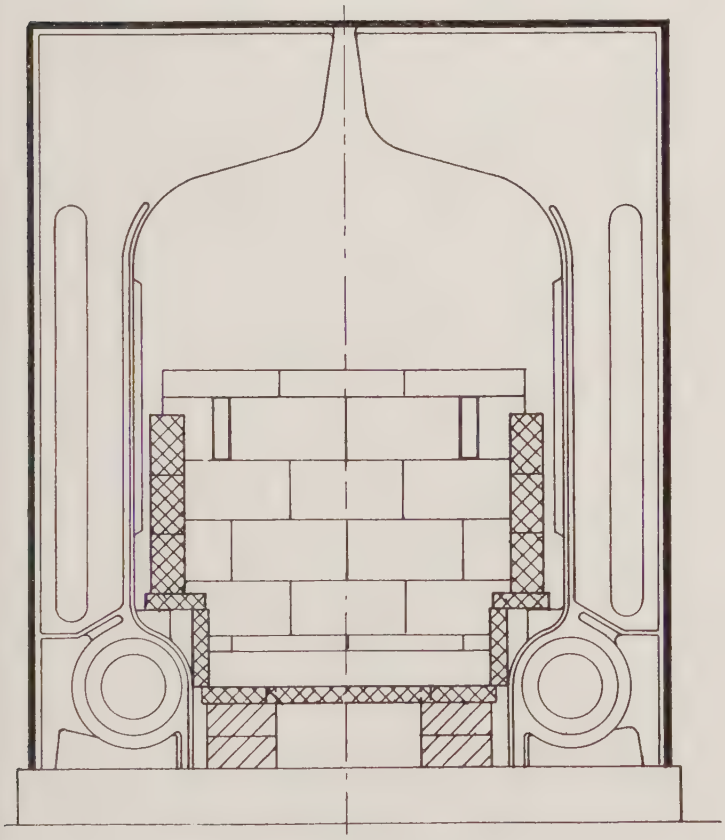

Fig. 2 - Traditional refractory bricks

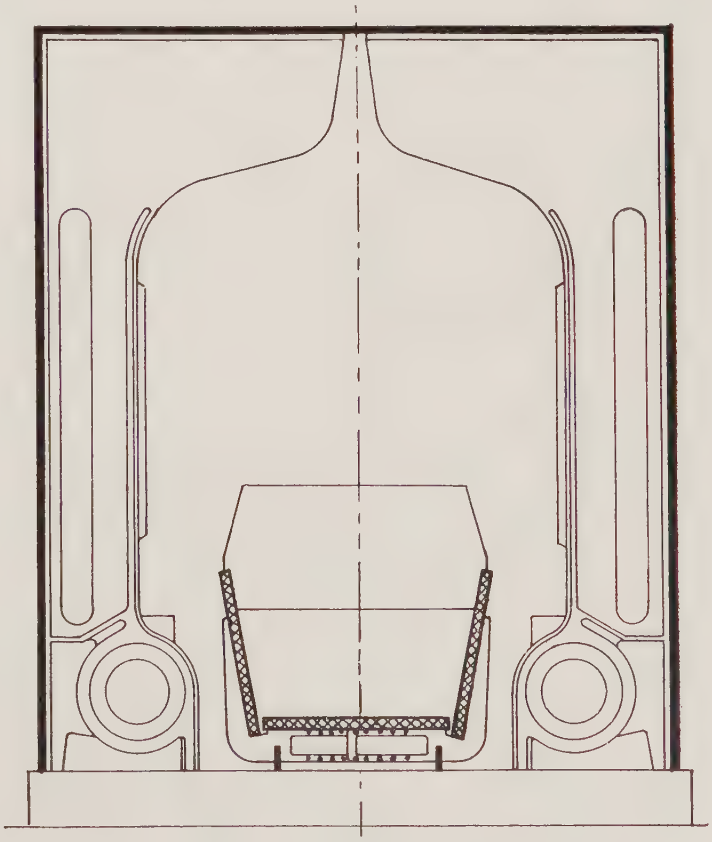

Fig. 3 - Newly designed refractory system

last set of experimental tests shows how great is the influence of the refractory system.

However carbon anhydride values registered at chimney bottom (point A) still show a low combustion efficiency (about 75 per cent). Checking again fuel heating temperature it was noted that this was too low for reducing fuel viscosity to get perfect atomization.

So heating temperature was raised to 158–167°F while combustion air was reduced to values allowing a more careful control. These adjustments brought the results shown on Table 4.

A glance at the experiments made brings the following considerations: for eliminating soot emission from heating installations it is necessary that the oil burner be perfectly adjusted.

From Table 1 and 2 an improvement in combustion conditions and a lower soot emission is noted when boiler wall temperature had been increased.

In the third and fourth set of experimental tests better results have been obtained using a new designed refractory lining and adopting the adjustments mentioned before.

Conclusions

At the end of this report concerning one of the most important problems of air pollution in which an attempt has been made to condense all the most interesting elements which may give a contribution to the solution of so important a problem a summary of what experience suggests in this field is given:

> The boiler should match the thermal requirements of the installation so that its walls may quickly reach the right temperature for a good combustion process.
>
> The oil burner should be designed and manufactured to give a perfect atomization of fuel oil assuring a correct air fuel mixture. The refractory lining should avoid the use of thick bricks to allow a fast heating to a red heat in the combustion chamber.
>
> The chimney should be designed with proper dimensions to allow the excess air value from the boiler to be as near as possible to the theoretical optimum.

Finally, fuel preheating should reach sufficiently high temperature to reduce fuel viscosity to obtain good atomization.

While it is thought that the means here suggested are a valid contribution to a solution to the air pollution problem concerning heating equipment the author hopes for suggestions which he is sure will be helpful in further improving the situation.

FUNDAMENTALS OF SMOKE EMISSION FROM LOW-TEMPERATURE FURNACES

G. UNDERWOOD, D. WATSON, S. G. McCONNELL, M. W. THRING, University of Sheffield, Great Britain.

SUMMARY: The mechanism of smoke generation is explained. It has been found that neither a reducing atmosphere nor smoke are needed to avoid scaling and decarburization of steel. There need be no smoke pollution from low-temperature furnaces, and if the volatiles, can be prevented from passing through regions of high temperature, then carbon formation is not likely to be severe, and the smoke can be burned at temperatures around 750°C to 800°C. Work is also described which enables the number of secondary air jets and their size, to be calculated for any particular furnace using secondary air.

What is smoke? To the man in the street, smoke is something dark that comes out of chimneys, and " should not be allowed " when it settles on his greenhouse glass, or on his wife's newly washed clothes. It is not so annoying when he sits in front of his open fire, and murmurs " what difference will my bit of smoke make, when so much is being given off at the works down the street? "

The comments above will be typical in many industrial areas, including Sheffield. This is due to the special type of work done, such as re-heating of billets and bars, and annealing of semi-finished articles, where it had been thought for many years that a long smoky flame was necessary to avoid excessive scaling and decarburization of steel.

Smoke is formed from the volatile matter of coal, and is due to incomplete combustion. In coal-burning appliances, the volatiles are usually released into a region of fairly high temperature, where secondary air must be introduced in order to burn them. The combustion of this volatile matter is always preceded by a certain amount of pyrolysis, both in the liberation, and the preheating in the outer regions of the flame. The process of combustion hence involves a race between the cracking of the hydrocarbons, and their combustion with the oxygen of the air. If the temperature of the flame is high, and the air is not well mixed with the volatiles, then carbon formation will be severe, since the initially small particles of carbon will have had time to agglomerate. If, on the other hand, the mixing is very good, and the air is preheated, then the combustion will take place very quickly, and the small particles of carbon will burn within the confines of the flame.

Smoke consists of two parts, viz., tarry matter and solid particles of carbon. Some years ago, it was not clear whether the reducing atmosphere in a low-temperature metallurgical furnace was the essential factor in minimising decarburization, or whether it was the presence of particles of carbonaceous matter that was effective. Mattocks[1] showed that neither the reducing atmosphere nor the smoke were needed, a small excess of air producing no increase in the decarburization or the scaling. He also examined the combustion of a distillation type smoke, and found that there was a lower limit, about 700°C, below which the combustion of the distillates would not occur. Preston[2] found that the combustion of bituminous coal was smokeless with only 20 per cent excess air, giving an oxygen concentration in the flue gases of 4 per cent, and that the soot formed would not burn below about 750°C.

Gerrard[3] showed that an " artificial " soot made by the pyrolysis of acetylene would not burn at an appreciable rate below a temperature of 720°C, and that variation in the particle size of the soot had a greater effect on the rate of combustion than had the temperature. Underwood[4] in an apparatus somewhat different to that of Mattocks, found that the volatiles distilled from a bed of coal at a temperature of 600°C could be ignited and burned with preheated air at a temperature of 750°C, and that under these conditions, 85 per cent of the smoke could be burned in less than 0·5 seconds using only 60 per cent of the air theoretically necessary to burn all the volatiles, the smokeburning in preference to other combustibles such as methane. It was also found that smoke could be ignited and burned at a temperature as low as 650°C, although the average temperature of the bed of coal was only 570°C, and that at no time before ignition had the smoke been heated to a temperature higher than 650°C.

In an investigation by the model technique of the mixing of secondary air jets over a fuel bed in coal-fired appliances, considering the problem to be that of a jet projected into a transverse air stream, Clamp[5] has confirmed that the larger the number of jets the greater the entrainment and the higher the combustion efficiency. He also gives formulae and worked examples showing how the path of the jet can be estimated, and it can, therefore, be found whether there will be sufficient penetration to cover the fuel bed. Two techniques were employed, one in which water models were used, photographs being taken of dye injected into the jet stream, and another using air models with nitrous oxide as a tracer and an infra-red gas analyser as the detector.

It is necessary to know the relationship between the smoking tendency of a coal and its analysis, because then suitable coals can be chosen for any particular appliance. Unfinished work by McConnell[6] indicates that over the range 15 to 40 per cent volatile matter on the dry-ash-free-basis, a relationship exists as below:

Smoke (wt per cent of d.a.f. coal) $= 0{\cdot}17$ (V.M.—3·4)

It has also been found that over this range of coals, at an air-smoke temperature of 750°C, a fixed percentage of the smoke is burned when a certain proportion of the air theoretically necessary to burn all the volatiles is admitted; e.g. 60 per cent of this theoretical air always burns about 88 per cent of the distillation smoke which would be obtained if no air were used. It is of interest to note here that Mattocks and Gerrard used thermal precipitators, collecting the smoke on a water-cooled aluminium cone, Underwood a water-cooled stainless steel filter disc, and McConnell an electrostatic precipitator, the last two workers treating all the combustion gases to measure the smoke.

McConnell is also analysing the combustion gases by gas-chromatography, one of the few known applications of this modern technique to such gases. It is known that by using oxygen-free nitrogen as a carrier, the gases H_2, CO, CH_4, C_2H_6, and CO_2 can be estimated, and that using argon as the carrier, the nitrogen can also be determined, but it is hoped that in addition to these, by using hydrogen as the carrier gas, the saturated and unsaturated hydrocarbons up to C_4 can be recognized and measured.

Most coals contain a few per cent of sulphur, which will be oxidized when the coal is burned. Wherever we can see smoke, then there will be quantities of invisible sulphur dioxide, and it has been suggested that atmospheric pollution is aggravated by the presence of solid soot particles in gases containing sulphur dioxide, which might not be such a serious pollutant provided no solids are emitted from the chimney stack. To test the significance of the argument, Watson[7] is investigating the reaction between sulphur dioxide and coal smoke.

A continuous supply of a distillation type smoke is allowed to react with sulphur dioxide in a heated flue. After being collected on an electrostatic precipitator, the solid smoke is removed and analysed for sulphur content and free acidity. It has been found that although the percentage of sulphur in the soot increases, there is no measurable increase in the free acidity, neither is any sulphur dioxide desorbed on standing, which indicates that this process cannot account for the highly acid smuts produced from some chimney stacks.

We have seen, then, that there need be no smoke pollution from low-temperature furnaces, that smoky atmospheres are not necessary for the correct treatment of the steel, and that if the volatiles can be prevented from passing through regions of high temperature, then carbon formation is not likely to be severe, and the smoke can be burned at temperatures around 750°C to 800°C. Work is also described which enables the number of secondary air jets, and their size, to be calculated for any particular furnace using secondary air. All the investigations described here were part of a programme of extra-mural work carried out for the Fuel Research Station at Sheffield University, and were supported by financial aid from the Sheffield and District Clean Air Committee.

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III. 39

COAL AND MODERN EQUIPMENT IN RELATION TO ECONOMY AND CLEAN AIR

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SUMMARY: Coal is our main indigenous fuel and is the most economical when used in the correct appliance. Coal is at least as efficient as oil when used in modern properly maintained appliances. When so used, coal does not create a greater smoke problem than oil. Energetic action is being taken to control the fines content of coal and to maintain more consistent quality. A list of typical well-run plants is appended.

In recent times large scale industry has expanded only in those countries with large indigenous fuel resources. Industrial Britain has relied on indigenous coal and will continue to expand and prosper only if the advantages and economies of her coal are fully exploited. Coal of the right type and of consistent quality can be the most economic of all primary fuels for steam-raising and space-heating when used with the correct appliance.

By recent Ministerial order industrial concerns situated in a smoke controlled area are now permitted to use bituminous fuel in modern mechanical coal-burning equipment. This is official recognition of the fact that mechanical coal stokers properly operated comply with the requirements of the Clean Air Act just as well as plant using other types of fuel.

Oil is not indigenous and all our requirements may be dependent on external political events. No general shortage of crude oil is expected for many years but there are the problems of quality as well as of "refinery balance" which could have important repercussions on the future price of fuel oils. Oil is claimed to give little or no emission of smoke, dust or grit during combustion and to be more controllable in this respect than bituminous coal. These claims are not wholly valid. Coal of the correct size and of consistent quality burned in the right type of appliance can be consumed without production of smoke and with minimal grit emission. The higher hydrogen content of oil makes it liable to produce proportionally larger quantities of sulphuric acid vapour. At present the Clean Air Act is not concerned with sulphur dioxide, but it is probably true that sulphur is a greater danger than smoke or grit to health and to the fabric of buildings.

In nearly all cases where before-and-after comparisons of efficiency on the conversion of plant from coal to oil burning have been made, the comparison has been between outmoded, worn and inefficient coal appliances and up-to-date oil apparatus. With the proper appliances, burning suitable coal and properly operated, it is practically impossible to produce smoke. Modern solid-fuel-fired installations give high efficiency, reliability, labour-saving operation, cleanliness in operation, no smell, silent running and full automaticity including completely enclosed automatic delivery of coal and extraction of ash and dust. Many hundreds of completely successful and economically operated plants fired with coal are as suitable for fully automatic control as those fired with other fuels. For industrial and other users of fuel who are considering the installation of new steam-raising or space-heating plant or the modification of their existing firing equipment, coal will be found to compare favourably with most fuels, both as to cost and as to amenity.

Oil has its problems: collectors have had sometimes to be installed to combat the nuisance arising from the emission of highly acidic smuts; trouble has also been experienced due to corrosion and the formation of deposits on the "back-end" of plant; chimneys and brickwork have suffered from the ravages of the gaseous effluents. Much trouble has also been experienced from smoke emission, particularly on so-called oil conversion plants. (Motorists who have followed diesel lorries on main roads need no convincing of the nuisance of smoke emission). Quite recently one Chief Public Health Inspector stated that in his city he had experienced more smoke troubles from plant fired by oil than from any other type of fuel; another stated that he was seriously concerned about the emission of smuts.

The National Coal Board realize that the most important problems associated with the use of coal for steam-raising purposes are quality and consistency. Both factors are of paramount importance where the Clean Air Act and economy are concerned. Increased productivity in the mines has tended to result in a higher fines content, the significance of which in relation to combustion and handling equipment is fully appreciated by the Board. Energetic action is being taken to control the fines content and to supply coal more consistent in quality. This will be of inestimable value to designers, manufacturers and users of firing equipment. It will take time and money, but it is the Board's firm endeavour to keep down prices so that coal in terms of cost per therm will be the most attractive primary fuel

In the domestic market the Board is doing all in its power to increase the production of smokeless fuels for space-heating. This is referred to in another paper, "Development of New Smokeless Fuels," which describes the work in progress to bring new processes for smokeless briquetting and the treatment of coal from the laboratory stage to that of commercial production.

As previously stated, many coal-fired plants are out-moded, dirty and inefficient. There is no doubt that if instead of converting them to oil they were brought up to date they would fully comply with the requirements of the Act and at the same time be as economical or even more economical than oil-fired plant. For that reason we have made a list (Annex) of typical well-operated, clean and efficient coal plants in the ranges likely to be of most interest to members of this Conference. This list shows various types of modern well-operated, mechanically-fired and fully-instrumented steam-raising and space-heating plants.

We have especially requested that these plants be made available for inspection, by courtesy of the owners, for those members wishing to avail themselves of the offer and we hope that as many members as possible will do so. The list is fairly comprehensive and it should be possible for each individual to make a selection having regard to size, type and location. Naturally there are very many other similar plants and the National Coal Board would be glad to arrange facilities for anyone requiring information about plants not included in the list.

III. 39

ANNEX

Name of Owner and Location of Plant	Smoke Control Area	Type of Boiler and Size (1000s p.p.h.)	No. of Boilers	Type of Firing Equipment	Quality of Fuel Burned
Messrs. Lewis Ltd., Leicester	Leicester No. 2 Exemption granted	Lumby Colonial 7	2	Ashwell & Nesbitt Underfeed Stoker	Donisthorpe Untreated Smalls
Leicester Corporation, Leicester	Leicester No. 3 Exemption granted	Cochran 2·6	1	Ashwell & Nesbitt Underfeed Stoker	Nailstone Doubles Desford Deep D.S. Nuts
Messrs. Marshall & Snelgrove, Leicester	Leicester No. 2 Exemption granted	Sectional Hot Water 1	4	Ashwell & Nesbitt Underfeed Stoker	Bestwood Washed Beans
Raleigh Industries, Nottingham	—	Ruston Thermax	4	Bennis Chain Grate	Bestwood Washed Smalls
		Ruston Thermax	1	Coking Stoker	Babbington Washed Smalls
		Ruston Thermax	1	Hodgkinson Low Ram	,, ,,
		Lancashires	4	Bennis Sprinklers	,, ,,
		Ruston Thermax	5	Bennis Coking	,, ,,
Wards Bridge School, Wednesfield	Wednesfield No. 2 Exemption probable	Sectional Colonel Heating Boiler	3	Ashwell & Nesbitt Iron Fireman ALC3	Cannock Chase Washed D.S. Nuts
Yale & Towne Ltd., Wednesfield	—	Ruston Thermax (Vertical)	3	Ashwell & Nesbitt Iron Fireman	Mid-Cannock D.S. Nuts
N.C.B. Walsall Wood Colliery (Baths)	—	Danks Economic 5·78	2	Chain grate	—
J. Sankey & Sons Ltd., Bilston	—	John Thompson Super Economic 15	3	John Thompson Chain grates	West Cannock No. 5 untreated Smalls
		John Thompson Super Economic 10	2	John Thompson Chain grates	,, ,,
Rolls Royce, Crew	—	John Thompson Super Economic 15	Battery	Hodgkinson Low Ram	—
Gleniffer Laundry, Catford	Lewisham No. 3	Penman Economic 12	3	Oldbury Chain grates	Hatfield Washed Smalls
Gestetner Ltd., Tottenham	None Exemption probable	Robey Economic 8	5	Hodgkinson Low Ram	Northumberland Singles
Vandervell Products Ltd., Maidenhead	None Exemption probable	Danks Economic 10	3	Chain grates	Eastwood Washed Smalls
		Cochran (standby) 5	1	Ivko Underfeed	Donisthorpe Singles
Charing Cross Hotel, British Railways	Westminster Area No. 2	Large Sectional Heating Boilers	4	Riley Underfeed Stokers	Midland Washed Singles

—continued

ANNEX—*continued*

NAME OF OWNER AND LOCATION OF PLANT	SMOKE CONTROL AREA	TYPE OF BOILER AND SIZE (1000s p.p.h.)	NO. OF BOILERS	TYPE OF FIRING EQUIPMENT	QUALITY OF FUEL BURNED
Portsea Hall (Marcus Investments (Edgware Road) Ltd.)	Proposed Paddington No. 1 Exemption probable	Ideal Britannia No. 414 K.C.I. Sectional	5	Hopes Underfeed	Northern Washed Singles
Nottingham General Hospital	None Exemption expected	Horizontal Thermax 12	3	Hodgkinson Low Ram	Gedling Washed Singles
James Hole & Co. Ltd., Castle Brewery, Newark	—	H.T. Thermax 15	1	Bennis Chain grate	Ollerton Washed Smalls
N.C.B. (C.E.E., Bretby)	—	Adamsons Economic 5 Danks Economic 11·5	2 1	Oldbury Chain Oldbury Chain	Donisthorpe Untreated Smalls ,, ,,
Threlfalls Brewery Ltd., Liverpool	Exemption granted	Economic	—	Chain grates	—
Bents Brewery Ltd., Liverpool	Exemption granted	Lancashires	—	Hodgkinson Low Ram	—
Liverpool Exchange Buildings, Liverpool	Exemption granted	Economic Sectional Boiler	4	Hodgkinson Low Ram Underfeed Stoker	—

V. 40

INTERNATIONAL PROBLEMS RELATING TO THE CONTROL, THE INSPECTION AND THE ASSESSMENT OF AIR POLLUTION

Dr. rer. nat. HELMUT BERGE, Agrikulturchemisches Institut, Heilingenhaus Bez, Düsseldorf, Germany.

SUMMARY: A distinction is drawn between methods of control applied to emissions and immissions.* Control should be exercised over the level of pollution by taking as a guide the degree by which the environment is affected, e.g. the level of damage to plants and buildings. Control of immissions in this way takes into account such factors as industrial concentration. As far as is known only the U.S.S.R. has a law which deals with immissions.

I am delighted once again this year to have the opportunity of speaking to an international audience about the most urgent problems in connection with the inspection and assessment of air pollution. Even before I made similar statements in 1958 at the Fourth International Congress of the Society for Research on Nutrition and Vital Substances, I have always stressed the fact that a satisfactory solution of those problems which are common throughout the industrial world and which cannot be disregarded, may only be achieved on an international basis. This conclusion is in the interests not only of the natural sciences and medicine but often of the prevalent economic factors and in particular of the factors relating to a free economy and technical interests.

We have to discriminate between methods of control applied to emissions that is to say to impurities thrown out or deposited and to immission* which are the results thereof. The control of emissions should be an " internal industrial " concern, perhaps to a certain extent under state supervision. The protection of the human being, and of the living and inanimate world which surrounds him, should be served by the control of immissions. The fact that unobjectionable, and in my opinion unimportant, emissions from the numerous smoke, exhaust gas and dust sources of a particular factory can develop into objectionable immissions is the best proof of these demands. This, of course, could apply to several undertakings of the same or of different kinds. A comprehensive consideration of all the inter-reacting interests in connection with the problem of air pollution can only be achieved if the final control of immissions is in the hands of the administration of justice and the temporary control of emissions rests with the individual firms.

I now quote examples which show why the control of immissions is more important than the control of emissions:

Wherever immissions affect the living and the inanimate world they can be examined at any time objectively and without interference.

Emissions on the other hand can only be controlled with the knowledge and approval of those responsible for their creation which in its turn permits of interference and adaptation.

The control of immissions takes into account the numerous factors which frequently affect the damage done, namely climatic, orographic, edaphic and biotic. Even when the exhaust gas, the dust and the smoke sources are constant the degree of damage done may vary according to the presence or absence of these factors.

Control of emissions does not permit of a consideration of these factors which often determine damage or the extent of damage.

As far as I know only the U.S.S.R. has a law which takes immissions as a basis of assessment in connection with air pollution. For Germany and for all countries with the same or with similar laws, I would, therefore, say the following:

The control of immissions is normal, and provision is made in Section 906 of the B.G.B. for control of noises as well as of air impurities caused by exhaust gases, dust and smoke. When testing an inebriated man one considers the alcohol content in his blood, which corresponds to the immissions, and not the amount of alcohol consumed, which would correspond to the emissions.

On the other hand we are familiar with the control of emissions in connection with the assessment of water impurities. The degree and the extent of pollution of our flowing and static water has in some instances reached such catastrophic conditions that one can only view further developments with anxiety. The pollution of our drinking water is the result of the control of emissions which has been carried on for years. If we disregard minor cases, and others which have been exaggerated, we find that the air pollution is also in part catastrophic and this is due to a certain extent to the system of assessing emissions mostly during the building of factories and the approval of new plant and the like.

The control of immissions permits of the objective assessment of the actual situation which cannot be said of the control of emissions and it should be borne in mind that the latter can only be carried out in respect of those industrial undertakings which fall within the terms of the law. The insubstantial emissions from an undertaking which is subject to public control, if supplemented by emissions from other sources (likewise under public control) can lead to substantial air pollution with damaging results to plants, animals and men. A similar state of affairs can arise in connection with a large industrial firm where negligible emissions (be they of gases, dusts or smokes), controlled by law, assume substantial and damaging proportions (immissions) in combination with emissions from other sources which may not fall under the terms of public supervision.

The control of immissions, unlike the control of emissions, is not only the method which permits of the best examination, and in consequence of the timely exclusion of damaging effects, but is also the method which most readily enables the scientists and technicians concerned with air pollution to take preventive action.

The control of immissions, in contrast to the control of emissions is realistic in so far as it measures and considers those gaseous dusty and smoky excretions which do not pass through what one might call the normal exit channels of a plant, be it chimney, filter drain, etc. It is surprising how often damage is caused by emissions from irregular exits, e.g. from cracks, windows, etc.—outlets which are not envisaged as

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*The word " IMMISSION " is defined as " Insertion, injection, admission, introduction. The opposite of 'Emission.' " (O.E.D.) —*Ed.*

such—and all this when the emissions at the normal recognized point of exit, e.g. chimney mouth, are normal. I would quote as a further example the frequent breakdowns—the interruption of the supply of electric current and other unavoidable (or sometimes avoidable), undesirable incidents which often escape the control of emissions but which would be noticed by a control of the immissions.

The control of immissions is valuable from every point of view. It is more closely related to actuality than any form of emission control. It can be not regarded—but it frequently is—as an obstacle or a detriment to economic planning and expansion especially as economic planning and technical development could take into consideration the most detailed data of an immission law and industry itself, when establishing new branches and works in otherwise unaffected areas, could derive benefits from such a law.

In addition to an official assessment of immissions which would be accepted as the proper basis for all claims an international classification is also desirable which would relate to the various concepts and forms of immissions. Personally I use and recommend the following specification for vegetation:—

1. Acute immissions, i.e. all influences which cause the destruction of internal or external vegetative parts.
2. Direct and chronic immissions, i.e. those which cause functional disturbances.
3. Indirect and chronic immissions, i.e. those which do not cause one or more physiological disturbances but which are nevertheless responsible for retarded growth or reduced yield or production.

I should also like to suggest the adoption of these sub-divisions of the general concept of immissions for the assessment of their effects on men and animals.

As far as the method of air and plant investigation is concerned, I am not at the moment in a position to recommend a specific method for international use. There are far too many imponderables in this field and it is to be hoped that the extensive research work recently commenced in this connection will lead to clear results which may be internationally adopted.

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IV. 41

ATMOSPHERIC POLLUTION IN THE PARIS AREA

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SUMMARY: The authors describe the measurements taken of various kinds of air pollution in the Paris area, and the results obtained. Comparisons between Paris and London or Glasgow are made. The laws in operation in France are outlined. While industrial establishments can be effectively controlled by the force of Inspectors set up under these laws, domestic pollution can only be dealt with by technical or economic changes. In the long-term, pollution should be dealt with by zoning and the creation of green belts. In the meantime a wider use of gas, sulphur-free petroleum products and district heating would provide a partial solution.

Atmospheric pollution is a question which is the concern of thousands of Frenchmen and rightly so. In fact there is in France an interministerial commission (under the Chairmanship of Professor Raymond and of which we are members) responsible for studying the important public health and town planning problem of atmospheric pollution.

What must first be fully understood is the nature and degree of pollution of towns, cities and built-up areas.

For the detection of these factors, there exist in the Paris area several laboratories officially appointed by the Prefectoral Administration to follow its evolution, to detect causes and to ascertain damage. One of these laboratories is the Municipal Laboratory, another is the Toxicological Laboratory and the third is The City of Paris Public Health Laboratory. It is the work of the latter which I would like to discuss with you more particularly, under the aegis of the Association Gènèrale des Hygiènistes et techniciens municipaux (the General Association of Public Health Hygienists and Municipal Engineers).

The City of Paris Public Health Laboratory of which I have been the head for several years and which during this time has remained under my direct authority, is at present supervised by Dr. Coin.

Our collaborator, Mr. Pelletier, deals more particularly with the question which concerns us today. Here is what we have to say on the subject.

In this account we are not dealing with cases of individual atmospheric pollution due to a given factory. Our task is to define the dominant character and the overall distribution of atmospheric pollution reaching the population of the Paris area as a whole. This area covers approximately the Seine Department (about 5½-million inhabitants). Shortly we hope to see our jurisdiction extending to the boundaries of the Paris district (about 8 million inhabitants).

Before defining the means to combat atmospheric pollution, we must know the *nature* of the forms of pollution which are most dangerous to health, their *origin* and their *distribution* over the territory considered. Only those forms of pollution in suspension in the air, those which penetrate into our lungs, will be considered here, those collected by precipitation, that is to say at the end of the atmospheric pollution cycle, will be excluded.

Having thus defined the broad lines of the programme for the investigation of atmospheric pollution in the Paris area by the City of Paris Public Health Laboratory, it follows that the *methods selected for these measurements are essentially volumetric.*

Furthermore, experience having shown considerable and unexpected variations from one moment to another in the concentration of air-borne pollution *sampling of this pollution must be continuous.*

As a result, the choice of methods of measurement is limited to recording instruments giving instantaneous variations of the polluting substance or instruments which indicate the average concentration of the pollution per unit volume of air over a fairly long period.

Having presented these preliminary ideas, I would like your permission to hand over to Mr. Pelletier who will explain briefly to you the reasons behind his choice of pollution indices, the results obtained by these methods and the interpretation of these results. He will then give you our opinion regarding the comparison, from the point of view of atmospheric pollution, between London and Paris.

After a few words on atmospheric pollution resulting from motor car traffic and the French laws relating to the problem of pollution in general, I will then resume in order to give you a very brief summary of the preventive means we are contemplating in France and particularly in Paris to prevent this very serious public health problem which we call atmospheric pollution becoming more acute in the years to come.

Pollution indices chosen

(1) *Carbon dioxide* (CO_2).—This substance was regularly determined for 30 years (1880 to 1910) in the centre and on the outskirts of Paris. Each determination included the average daily concentration.

Although the amounts of this substance observed in the open air in large towns remain below that at which any physiological effect appears, it was considered advantageous to resume systematic measurement in 1954 for two main reasons:

(*a*) The first, in order to check to see if the average CO_2 concentration in the Paris air had varied over the last 50 years.

(*b*) The second, because as carbon dioxide is the remains of all forms of carbon combustion which is still the basis of industry (in the wide sense of human activities) knowledge of the concentration of this substance in the air may serve in determining the relative importance of the other polluting substances having regard to the extent of this combustion.

Naturally, allowance has to be made for the CO_2 exhaled by the inhabitants of the territory considered when breathing. For a population of 5½-million inhabitants (equal to the population of the Seine Department) this is in the neighbourhood of $2.2–10^6$ tons per annum whereas the CO_2 arising from all forms of combustion amount to 20 million tons for this same territory. In other words, the influence of human breathing does not exceed 10 per cent of the whole of the CO_2 emissions for the year. However, in summer, when space-heating is not involved, this proportion may become much larger (of the order of 25 per cent). With this reservation, measurement of the ratio of concentration of pollution arising from the combustion of a carbon derivative and that of CO_2 will show whether preventive measures undertaken against this pollution are effective or not.

The measurement of atmospheric CO_2 can be achieved by recording (specific absorption in infra-red rays) or by average sampling in an alkaline solution. In this case it is the overall acidity of the air which is measured, but this can be taken as CO_2, experience having shown that acidity due to other substances does not generally exceed 1/300 of the CO_2 concentration in the air.

For these measurement results to be valid when they are compared with those of other polluting substances, it is essential that they are sufficiently accurate (to within 1 ppm, or better than 1/300 of the quantity to be determined). Because of this, this determination has the disadvantage of being difficult to use as a simple routine method. In addition it has only been carried out so far in the centre of Paris (AB).

(2) *Sulphur dioxide* (SO_2).—This substance on the other hand lends itself very well to routine determination. In fact, in the method used in Great Britain and in France (Public Health Laboratory) an overall determination of the strong acidity of the air is carried out. Investigations carried out in the United Kingdom have shown that this simple measurement was sufficiently representative of atmospheric SO_2.

As in the case of English towns, this substance appears to be the most dangerous at the present time in the Paris area. Its distribution in this area will be seen further on.

(3) *Smoke and fine dusts.*—The filtration of the air through a filter paper (CA 32 in France or Whatmann in Great Britain) produces a fairly black mark the reflectance of which, measured with the eye or with the reflectometer, gives a fairly accurate assessment of the weight of smoke gathered per unit surface area of filter.

The same SF instrument (abbreviation for SO_2-Fumèes) used to collect the SO_2 also samples the smoke. This instrument which is simple and robust requires only a very small electric current. It generally gives averages of 24 or 48 hours.

The measurement of smoke by reflectometry should be calibrated with reference to a gravimetric measurement. The method applied in France consists in comparing the monthly average obtained on paper filters with the monthly average weights to fine dusts gathered by continuous filtration of the air for one month through Teflon wool at the same point. This practice is laborious (it takes at least one year) but it is the only valid method which enables measurements of blackening to be converted into weight of smoke per unit surface area of filter. In fact it considerably attenuates the transient fluctuations of the ratio which exists between the colour and the density of the smoke (Fig. 1).

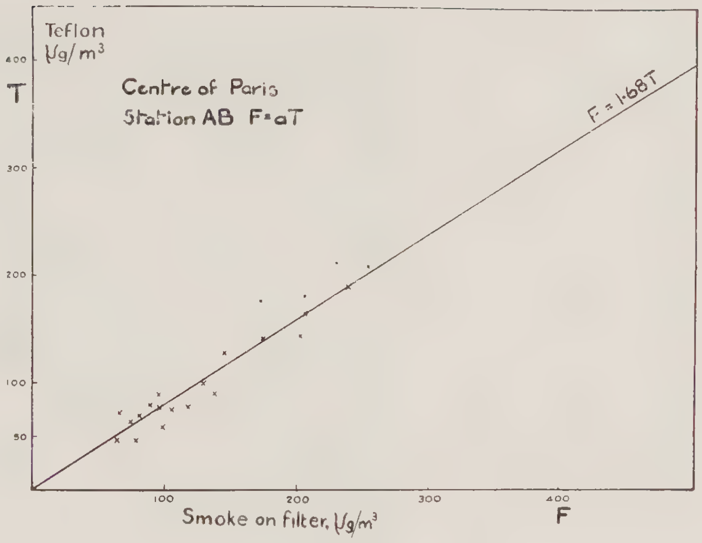

Fig. 1

These average measurements are supplemented by a continuous sampling of smoke by filtration through a paper disc which is rotated at the rate of 1 revolution in 30 hours and reflectometric reading of the dust gathered.

Results

The present system of SF stations comprises 14 instruments installed at 13 different sites (Fig. 2). The site AB has two instruments in parallel. Sites 1 and 2 are above one another; the instrument (1) at 10m and instrument (2) at 50m above ground. Readings are taken at the stations every day between 2 p.m. and 5.30 p.m. and the average worked out for the day.

Daily cycle of atmospheric pollution in the centre of Paris (AB)

Smoke recording is at present carried out only on weekdays and only in the centre of Paris. The average daily cycle obtained for the summer and winter seasons is shown on graph No. 3.

In the case of Summer 1958: a minimum of 67 $\mu g/m^3$ between 2 and 3 a.m.; a maximum of 190 $\mu g/m^3$ between 8 and 9 a.m.; a secondary minimum around 2–3 p.m. (70 μg) and a secondary maximum between 8 and 9 p.m. (90μg).

In the case of Winter 1958/1959: minimum of 140 $\mu g/m^3$ between 3 and 4 a.m.; maximum with 475 $\mu g/m^3$ between 9 a.m. and 10 a.m.; secondary minimum around 4–5 p.m. with 255 $\mu g/m^3$ and a secondary maximum between 7 and 8 p.m. (320 $\mu g/m^3$).

Weekly cycle

In the centre of Paris the minimum occurs on Sunday in the case of the three polluting substance CO_2, SO_2 and smoke under the probable influences of small industries and traffic (Fig. 4).

As regards the smoke, 15–35 per cent less is observed on Sunday depending upon the position of the stations.

In the case of SO_2 the minimum day is generally Sunday with 15–25 per cent less but in the industrial area (St. Denis) the minimum may be observed during the week.

Annual cycle

The Summer minimum is very marked in the Paris area.

This annual cycle is more accentuated the more residential the area in which the sampling station is situated.

This demonstrates the importance of the part played

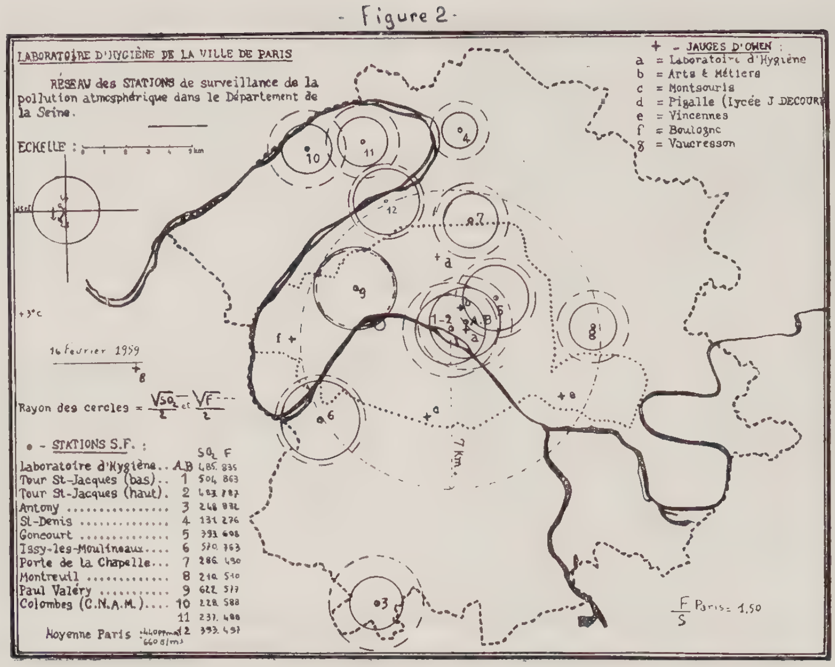
- Figure 2 -
LABORATOIRE D'HYGIÈNE DE LA VILLE DE PARIS
RÉSEAU des STATIONS de surveillance de la pollution atmosphérique dans le Département de la Seine.
ECHELLE :
0 1 2 3 4 5 km
+3°C
16 Février 1959
Rayon des cercles = √SO₂/2 et √F/2
• - STATIONS S.F. :
SO₂ F
Laboratoire d'Hygiène.. A.B 485 835
Tour St-Jacques (bas).. 1 504 863
Tour St-Jacques (haut). 2 483 787
Antony 3 248 832
St-Denis 4 131 276
Goncourt 5 393 608
Issy-les-Moulineaux.... 6 570 363
Porte de la Chapelle... 7 286 490
Montreuil 8 210 510
Paul Valéry 9 622 517
Colombes (C.N.A.M.).... 10 228 588
11 237 488
Moyenne Paris 440 ppm / 660 g/m³ 12 393 497
+ - JAUGES D'OWEN :
a = Laboratoire d'Hygiène
b = Arts & Métiers
c = Montsouris
d = Pigalle (lycée J DECOUR
e = Vincennes
f = Boulogne
g = Vaucresson
F/S Paris = 1.50
7 Km

Fig. 2

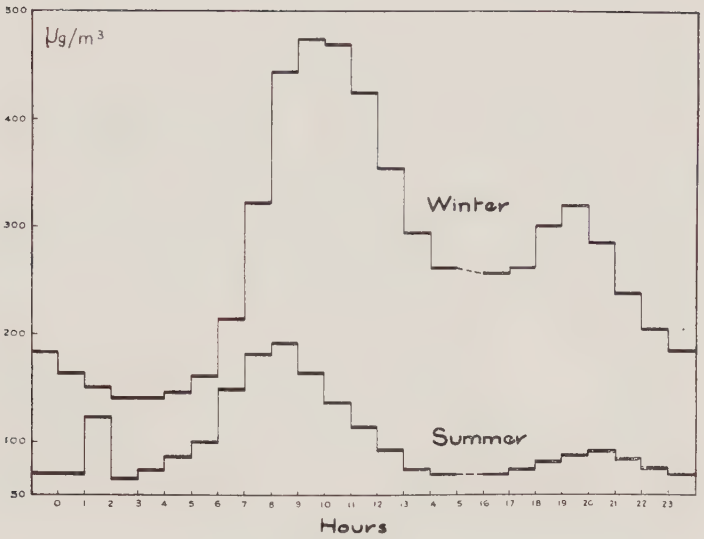

Fig. 3

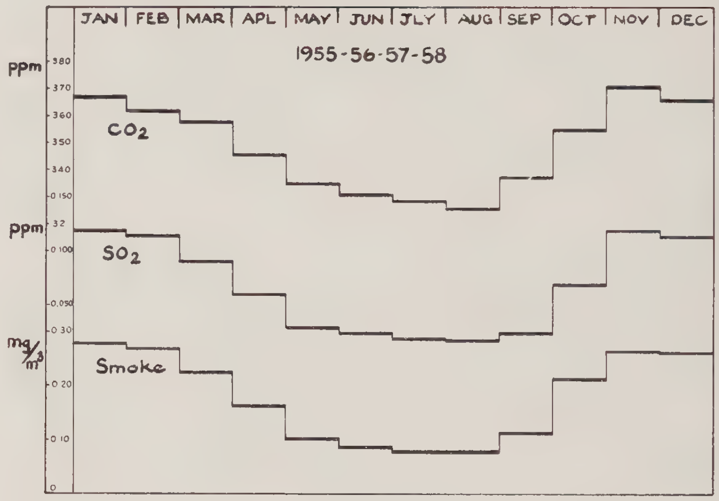

Fig. 5

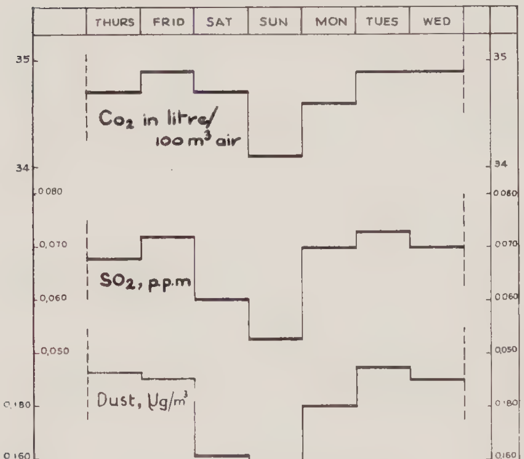

Fig. 4

by domestic fires in the pollution of the air in the Paris area.

In the centre of Paris (AB) the annual cycle of the three polluting substances CO_2 SO_2 and smoke are absolutely identical (Fig. 5).

The maps in Fig. 6 and 7 show the whole of the geographic distribution of the two polluting substances measured (SO_2 and smoke) during the winter season and the summer season. It will be noted that the sulphurous pollution is maximum both in summer and winter, in the Paris perimeter, at station 9 located to the west of Paris in a well-to-do quarter which is fairly open. This undoubtedly is due to the development of oil-fired central heating in modern apartments during winter and for water-heating during summer. The operating features of these boilers make them similar to the industrial type: they emit very little smoke but a large amount of oxides of sulphur.

The widespread development of this method of heating which is more convenient (lower labour costs) has for some years resulted in a disturbing increase in the discharge of SO_2 into the atmosphere of the capital.

In the centre of Paris, the annual averages obtained for CO_2 have varied very little over the last 5 years: 344–353 ppm. Averages for SO_2 vary between 0.06 and 0.07 ppm. and average for smoke between 0·15 and 0·20 mg/m³.

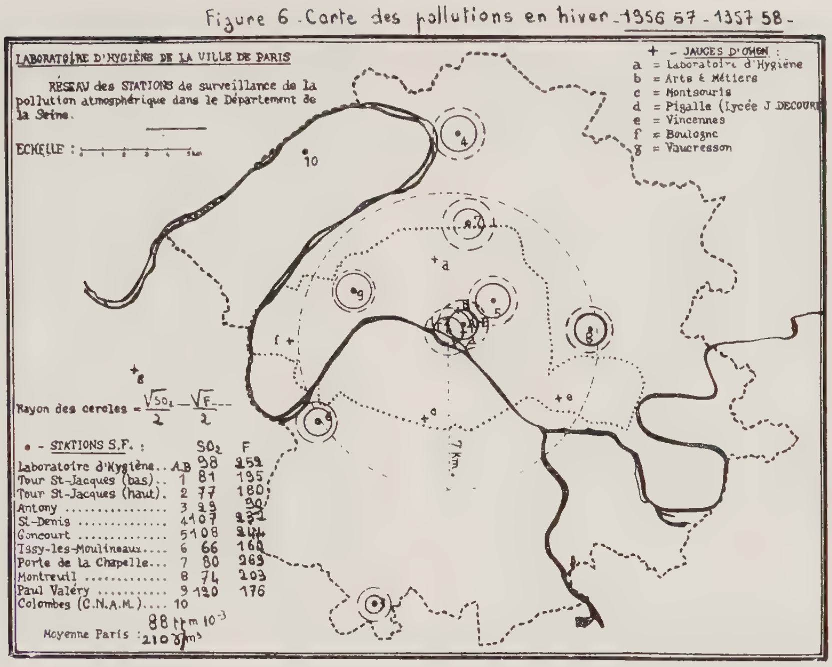
Figure 6 - Carte des pollutions en hiver - 1956 57 - 1957 58 -
LABORATOIRE D'HYGIÈNE DE LA VILLE DE PARIS
RÉSEAU des STATIONS de surveillance de la pollution atmosphérique dans le Département de la Seine.
ECHELLE :
+ - JAUGES D'OWEN :
a = Laboratoire d'Hygiène
b = Arts & Métiers
c = Montsouris
d = Pigalle (lycée J DECOUR)
e = Vincennes
f = Boulogne
g = Vaucresson
7 Km.
Rayon des cercles = $\frac{\sqrt{SO_2}}{2}$ — $\frac{\sqrt{F}}{2}$

• - STATIONS S.F. :		SO_2	F
Laboratoire d'Hygiène..	A.B	98	252
Tour St-Jacques (bas)..	1	81	195
Tour St-Jacques (haut).	2	77	180
Antony	3	29	90
St-Denis	4	107	232
Goncourt	5	108	244
Issy-les-Moulineaux....	6	66	160
Porte de la Chapelle...	7	80	263
Montreuil	8	74	203
Paul Valéry	9	120	176
Colombes (C.N.A.M.)....	10		

Moyenne Paris : 88 ppm 10^{-3} / 210 γ/m³

Fig. 6

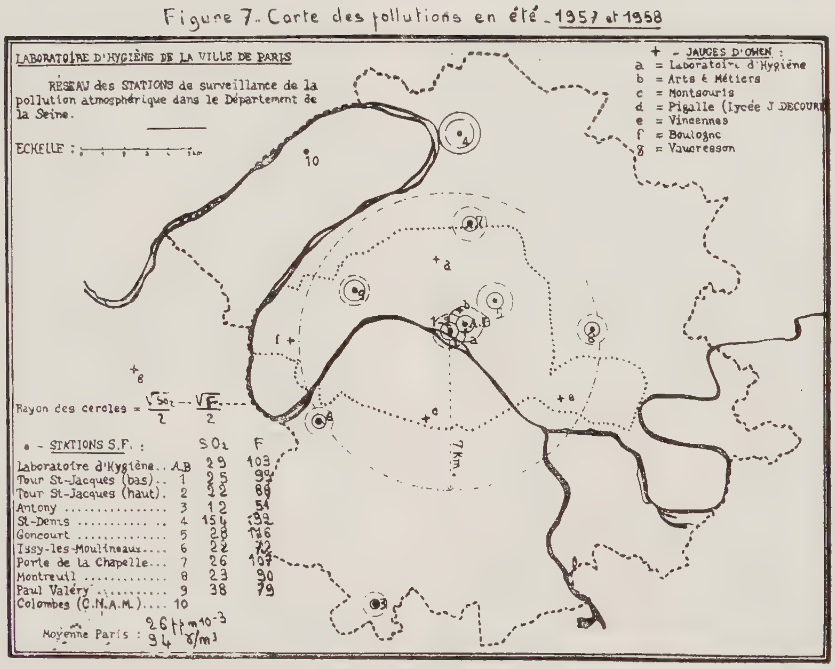
Figure 7 - Carte des pollutions en été - 1957 et 1958
LABORATOIRE D'HYGIÈNE DE LA VILLE DE PARIS
RÉSEAU des STATIONS de surveillance de la pollution atmosphérique dans le Département de la Seine.
ECHELLE :
+ - JAUGES D'OWEN :
a = Laboratoire d'Hygiène
b = Arts & Métiers
c = Montsouris
d = Pigalle (lycée J DECOUR)
e = Vincennes
f = Boulogne
g = Vaucresson
7 Km.
Rayon des cercles = $\frac{\sqrt{SO_2}}{2}$ — $\frac{\sqrt{F}}{2}$

• - STATIONS S.F. :		SO_2	F
Laboratoire d'Hygiène..	A.B	29	103
Tour St-Jacques (bas)..	1	25	99
Tour St-Jacques (haut).	2	22	88
Antony	3	12	54
St-Denis	4	154	192
Goncourt	5	28	116
Issy-les-Moulineaux....	6	22	72
Porte de la Chapelle...	7	26	107
Montreuil	8	23	90
Paul Valéry	9	38	79
Colombes (C.N.A.M.)....	10		

Moyenne Paris : 26 ppm 10^{-3} / 94 γ/m³

Fig. 7

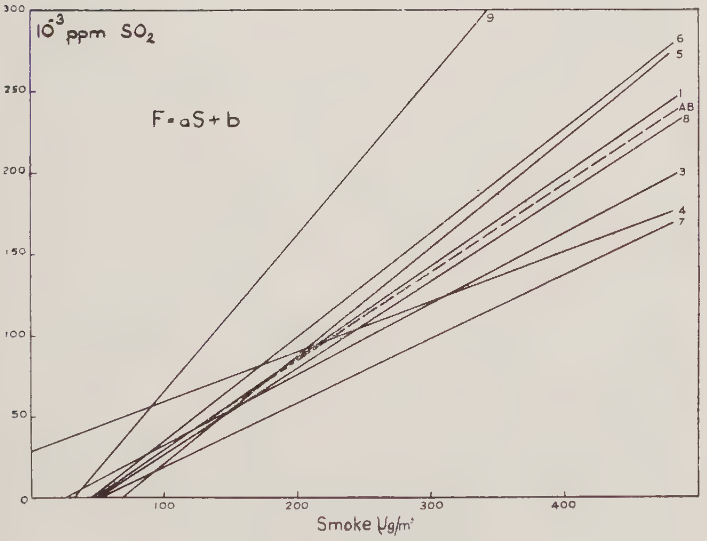

Fig. 8

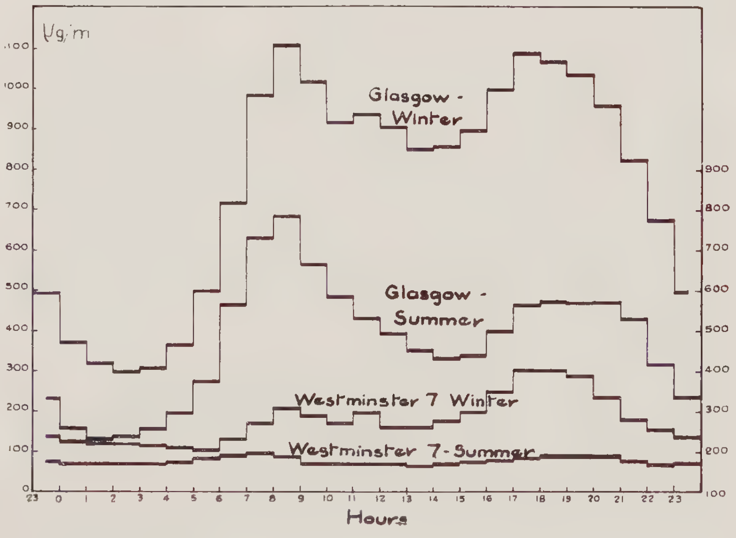

Fig. 9

Interpretation of the results

An attempt has been made to establish a relationship inside each station between the concentrations of each polluting substance (Fig. 8). It appears that in all the stations except two (4 and 7) an *approximately* linear relationship is found of the form:

$$(1)\ F=aS+b$$

where F represents the weight of smoke and S the SO_2 concentration in the air: "a" and "b" being representative coefficients for each station.

The coefficient "a" indicates the proportion of smoke gathered in relation to the SO_2 at the same place.

In the case of 8 stations in the Paris perimeter the average values found for "a" and "b" are: $-12<b<+65$ and $1<a<1{\cdot}9$ if F is expressed in microgrammes of smoke per m^3 air (reflectometric method) and S is expressed in 10^{-3} ppm. of SO_2.

At station 7 (Porte de la Chapelle) the relationship between S and F does not appear to be linear particularly near the threshold: "a" being in the neighbourhood of 2·5 in the case of heavy winter pollution and falling off considerably in the case of light pollution.

For the three *suburban* stations there is a relationship similar to (1) but where: $-12<b<+30$ and $2{\cdot}3<a<2{\cdot}6$.

Finally, the station at St. Denis (4), situated in a highly industrialized area has no linear relationship of the form (1). The SO_2 remains almost invariable whatever the smoke values, except in the case of the winter season where it appears a coefficient of $a = 3{\cdot}5$ is observed.

It can be regarded that the particularly industrial areas (such as 4 and even 7) have a relationship between S and F which is non-linear due to the fact of twofold pollution: domestic fires and industrial furnaces.

Linearity is much better when the dominant source of pollution is combustion in domestic fires. In this case it is convenient to observe different types according to whether the coefficient a or the constant b are high or low.

(*a*) If we consider the station of the *Paris perimeter* (radius of 7km about the centre) we see that a=1 at station 9 (16th district, west of Paris). That is to say taking into account the measuring units adopted (10^{-3} ppm. for SO_2 and microgrammes/m^3 for smoke), the smoke concentration here is equal to that of SO_2. On the other hand, assuming that linearity is maintained in the case of slight pollution, zero smoke very rarely corresponds with zero SO_2. For this station for instance, we find "b"=30μg/m^3. This level is the lowest of the perimeter stations of Paris (with the exception of station 12—Beaujon—situated near a relatively industrialized area).

To summarize, the west of Paris (16th District) is characterized by very low particle pollution and a very high sulphur pollution. This feature can be attributed to a predominance of oil-fired central-heating boilers in this quarter. It should be noted that the low particle pollution at this station may also be partly due to the position of the sampling instrument which is some distance away from the main traffic arteries in the quarter and is protected by screens of trees and fairly tall houses.

Station 5 installed in the east centre of Paris, in a populous and poor quarter at a junction of two very busy roads, has a high degree of dust precipitation and a fairly high degree of sulphur pollution. The coefficient "a" here is already about 1·5 and "b" is in the neighbourhood of 65 μg/m^3 and is the highest of the stations in the centre of Paris. Motor car traffic here is probably responsible for this high dust level.

Station 7 (Porte de la Chapelle) is situated in the north of Paris between a very populous quarter in the south-south-west and a very active and extensive industrial area in the north. In addition this station is located near one of the main roads out of Paris and between two marshalling yards with a steam locomotive depot. It will be observed that the relationship between F and S is more or less linear during the winter months in the case of heavy particle pollutions, at which season the influence of domestic fires is probably dominant. On the other hand, when the weather becomes warmer, the coefficient "a" which was in the neighbourhood of 2·5 (predominance of smoke) tends to drop—i.e. the SO_2 assumes a dominant character—the industrial influence then takes over from that of the domestic fires. The level "b" between 45 and 80 μg/m^3 remains one of the highest in Paris (traffic, steam locomotive depôt).

Another station No. 6 at Issy-les-Moulineaux in the south-west of Paris also has distinctive characteristics. It is located in the Seine valley surrounded by several large factories in a fairly populous quarter, dominated in the south-west and in the west by high, wooded hillsides. Pollution here exhibits considerable variations: very low minima (particularly in the case of SO_2) and very high maxima. The linearity of the relationship between F and S is fairly good here. This latter factor varies from zero and below (alkaline air) to high concentrations. The coefficient "a" in the neighbourhood of 1·6 indicates a considerable portion of SO_2 in the pollution and the level "b" of 45 μg/m^3 coincides with the average level for the centre of Paris. This wide amplitude in the variation of the polluting substances can be attributed to the position of the station near the edge of a large forest area and an area of average industrialization and dense population. If winds blow from the wooded slopes, the air here is very pure. Conversely, when the winds are light and from the centre of Paris, pollution accumulates in this valley and has difficulty in passing over this line of hills. (Fig. 2.)

The other five stations of the Paris perimeter exhibit good linearity between F and S.

"a" is between 1·75 and 1·9.

"b" is between 40 and 50.

(There is, however, an exception in the case of station 12 at the north-west limit of the Paris perimeter where "b" would be negative with a value in the neighbourhood of −10).

In this uniform whole, we find stations fairly highly polluted (AB and Tour St. Jacques 1, in the centre of Paris) and a station with very light pollution near the eastern limit of the Paris perimeter (station 8 at Montreuil).

Finally, the air in the centre of Paris is generally slightly less polluted at 53 m above ground than at 12 m above ground, in a proportion of between 5 and 10% in the case of SO_2 and smoke.

(*b*) As regards the *suburban stations*, it was seen above that the coefficient "a" was greater than 2. This means that the smoke here has a dominant character compared with SO_2.

In this category we find the least polluted station (No. 3 at Antony) in the southern suburbs, a non-industrial, residential area where the level "b"= 30 μg/m^3 and "a"=2·3.

The Colombes station (No. 10) in a residential area to the west of Paris and near a number of very large factories (for instance about 1 km south of a large power station) has atmospheric pollution similar to that found at Antony. Here "a"=2·55 and "b"= 22 μg/m^3.

The Gennevilliers (No. 11) station, 3 km east-north-east of station No. 10, is an area which is residential and has heavy industries and appears (we only have a few months observations so far) to have very similar features; "a"=2·6 and "b"=−10.

The negative character of "b" which we find at station 12 also located to the north-north-east of Paris seems to be due to the dominant sulphurous pollution from industries in summer.

This character is even more marked in the case of station 4 (St. Denis) in the north of Paris in the middle of a large industrial area. At this point the relationship between F and SO_2 is no longer linear. *The SO_2 here rarely drops below* 50 x 10^{-3} *ppm* and the smoke is very rarely below 50 μg/m³. In the cold weather, however, it seems that a certain linearity exists and "a" would be in the neighbourhood of 3·4 "b" being lower at −100 μg/m³. The difficulty of interpreting these results in this area where there is high sulphur pollution arises from the alternately dominant characters of domestic heating in the winter and industry in the summer.

Comparative tests between atmospheric pollution in London and Paris

From figures supplied by the annual reports of the Department of Scientific and Industrial Research we have attempted to compare features of sulphur and particle pollution between these two cities. This comparison is justified because the methods of sampling and analysis used are very similar.

The first comparison deals with the daily cycle of particle pollution in the centre of Paris and in the centre of London.

Our recordings at present cover only weekdays and we therefore compared them with the daily averages of the corresponding days in London.

The daily cycle in the centre of Paris has a very marked principal maximum in the morning, whereas in the centre of London (Westminster 7) there is no very apparent maximum or minimum. On the other hand, a very similar cycle to that in Paris is found at Glasgow 1 (Fig. 2 and 9).

The weekly cycle (Fig. 4) of pollution in Paris is very similar to that observed in Great Britain.

We observe 20 per cent less smoke and SO_2 on Sunday in the centre of Paris (23 per cent and 21 per cent at City 1 London).

Against this, the weekly cycle of SO_2 is very much attenuated at St. Denis (4), an industrial suburb of Paris, with 7 per cent less on Sunday, whereas at the same point the smoke cycle is normal (20 per cent).

This attenuated weekly cycle for SO_2 is found at Westminster 7 (5 per cent) and particularly at Glasgow 1 (3 per cent).

The annual cycles have also the same appearance. The amplitude of average seasonal variations at the centre of Paris $\dfrac{\text{winter average}}{\text{summer average}}$ is 2.2 in the case of smoke and 3.5 in the case of SO_2 (2.3 and 2.8 respectively at London City 1).

Finally, the smoke levels are much higher in London than in Paris. It seems there is about 70 *per cent more smoke* in winter in London than in Paris and only 20 *per cent more SO_2* in the same season. Against this, in summer there is only 25 per cent more smoke in London than in Paris but 2.25 times more SO_2.

Thus, London seems to have a greater background of industrial pollution than Paris and London domestic fires emit very much more smoke than those in Paris.

An attempt has been made to apply the expression (1) found for Paris to several station in Great Britain:

$$F = aS + b$$

In this way an appreciably linear relationship is observed between the polluting substances at the London stations: City 1, Lambeth 2 and Leyton 1 with "a" coefficients of 1·3, 2·4 and 3·9 and "b" constants of −13, −33 and −47. We see from this that City 1 exhibits a relationship between S and F similar to that observed in our stations Goncourt (5) or Beaujon (12), that Lambeth resembles Porte de la Chapelle (7) and Leyton 1 resembles Gennevilliers (11) or St. Denis (4).

On the other hand, the relationships are much less linear at Westminster 7 which would resemble our station at St. Denis (4) in many ways. Finally, at Glasgow 1 the relationship is hardly linear with approximate mean coefficients of "a"=7 and "b" =−150.

The coefficient $a=7$ which is much higher than any observed in Paris indicates considerable dust concentration in the industrial capital of Scotland and a relatively high level of SO_2.

Atmospheric pollution due to motor traffic

When the expression $F=aS+b$ is applicable, it can be assumed that to a certain extent, the term "b" represents the amount of traffic as well as "recycling" (deposited particles being lifted into the atmosphere again by the wind). This method of assessment would necessitate a complicated study and could only be applied to particle pollution and only when the SO_2 of industrial origin does not render the constant "b" negative.

It is also possible to draw up a balance of excess CO_2 in the atmosphere of a town in summer, as we have attempted (H. Grisollet and J. Pelletier—"La *Mètèorologie IV*, **47,** 1957, pp. 393–418). This method is already slightly more accurate provided the CO_2 arising from respiration is taken into account as we have seen above. Unfortunately, accurate CO_2 measurement does not lend itself much to routine work.

It is also possible to attempt to determine the "unburnt matter" from exhaust gases. Overall determination of the gaseous unburnt matter in the air is carried out at the Paris Public Health Laboratory by measuring the CO_2 contained in the air after "roasting" it at 900°. The difference between the CO_2 concentration thus obtained and the free CO_2 concentration existing at the same time in the air, corresponds to hydrocarbons, carbon monoxide and other carbonaceous gases in the atmosphere.

This determination, which is fairly difficult, has shown us that the excess CO_2 concentration thus obtained rarely exceeds a few ppm.

Another method which is fairly effective for measuring this pollution is the determination of carbon monoxide in the air (E. Effenberger, *Medizin-Meteorologische Hefte No.* 12–1957). Here again we encounter difficulties.

(1) This gas diffuses very quickly into the atmosphere and is only found there, fortunately, in very small quantities. It therefore has to be captured at traffic level.

(2) This measurement must be accurate to be usable (of the order of ppm). It can only be carried out in this case with costly and fragile recording instruments.

(3) Finally this gas is also emitted in appreciable quantities by domestic fires.

However it has been possible to note fairly high quantities of CO in the air of Paris at certain times

(Annuaire statistique de la Ville de Paris 1957–1958 —Imprimerie Municipale—Paris). These phenomena are rare: a few hours or a few days only per annum. At the time of very heavy pollution in February 1959. in Paris the concentration of this gas in the air did not exceed 30 ppm whereas at the same time the CO_2 amounted to 800 ppm the SO_2 exceeded 1 ppm and smoke 1·2 mg/m^3.

We see therefore that this gas is a poor indication of pollution and is not sensitive enough.

However the Laboratoire Municipal de la Prefecture de Police has been able to draw a map of air pollution by carbon monoxide in the roads and crossroads of Paris (Conjoncture Economique dans le Department—4th Quarter 1957—Imprimerie Municipale Paris). This laboratory has also shown that even when the wind is light, air taken at a height level with the second floor of buildings is hardly polluted with carbon monoxide.

The carbon monoxide concentration in the blood of policemen who are particularly exposed to those discharges has been measured by this same laboratory. It has been shown in this way that whilst not negligible, this concentration did not exceed that found in the case of average smokers.

As regards carcinogenic substances, the Municipal Laboratory has also found benzpyrene in the air in Paris, without being able to affirm whether this substance comes more particularly from motor car traffic or domestic fires. The greater frequency of cases of lung cancer in Paris compared with the country surrounding it, can be attributed as much to cigarette smoke as atmospheric pollution.

Legislation

This is mainly based in France, and in particular Paris, on the law of 19th December, 1917 relating to dangerous, insanitary and noxious establishments as amended by the laws of 20th April, 1932 (referred to as the Morizet Law) and 21st November, 1942.

This law classifies establishments into three categories:

(*a*) the first covers those which must be sited away from dwellings;

(*b*) the second, those only authorized in the neighbourhood of dwellings under certain restrictive conditions;

(*c*) the last concerns establishments, the installation of which is subject merely to a simple declaration to the Public Authorities.

The law of 15*th June*, 1943, *relating to town planning creates areas reserved for habitation in which establishments belonging to the first or second category cannot be set up.*

The law of 20th April, 1932, declares, in the first article:

> "It is forbidden for industrial, commercial or administrative establishments to emit smoke, soot, dusts, toxic or corrosive gases likely to inconvenience the neighbourhood or to pollute the atmosphere or to endanger public health or safety, agricultural production, preservation of monuments or the beauty of areas."

An order by the Prefect of Police dated 25th January, 1934, applies this law in the Seine Department to all users of furnaces consuming mineral fuels burning *more than* 20 *kg. fuel per hour.*

It is particularly prohibited, in urban centres and at less than 10 *km. from the perimeter of areas reserved for habitation, to use fuels containing more than* 2 *per cent sulphur.*

The emissions from these furnaces should not include more than 1 per cent carbon monoxide or contain more than 1·5 g. of dust per cubic metre. The overall quantity of dust emitted must never exceed 300 kg. an hour whatever the size of the plant.

The Service de l'Inspection des Etablissements Classés is responsible for applying this law which, as can be seen, covers only large furnaces (burning nearly half a ton of fuel per day).

In the Seine Department there are 25,000 classified establishments.

The supervision of these is carried out by a body of 22 Commissaires (engineers) assisted by 11 inspectors (non-engineers).

The law applying to non-classified establishments and to domestic fires is much less precise. It is only by virtue of the constitutional law of 1884 (Mayors' statute) and that of 15th February, 1902, on the protection of public health, that the communal magistrates have real powers over non-classified establishments, the Sanitary Regulations of the Department which stem from them include, among other things, in the Seine Departement, an article 26a, drafted as follows:

> "All fires whatever their size or fuel employed must, together with their accessories, be arranged and maintained in such a way as not to cause any dirt, odours or inconvenience to the neighbourhood, particularly by the generation of smoke, the discharge of sparks or soot and the emission of toxic or corrosive gases."

Enforcement of these health regulations is supervised by a body of inspectors (engineers) of the Service du Controle Technique de l'Hygiene de l'Habitation (Technical Inspection Department of the Public Health Service) made up of three divisional engineers and 22 engineers. At the present time, this inspection applies only within the Paris city boundaries and form only a small part of the duties of the Corps of Inspectors.

However, although these regulations can be applied quite effectively to classified establishments owing to there being relatively few of them, the difficulties that would be encountered in supervising the correct operation of nearly 3 million domestic fires cannot be overlooked. It certainly would appear that their dispersion renders any regulation covering their emissions inoperative and illusory. In this case it would be better to employ preventive methods which Dr. Besson whom I now invite to speak will discuss.

Atmospheric pollution prevention

The study of atmospheric pollution in the Paris area the main results which have been outlined in the preceding paragraphs, have shown that the immediate danger for the major part of the Paris population comes from the discharge of sulphur products into the air.

These are emitted, in order of priority, in the centre of Paris by domestic fires and in the northern suburbs of Paris by industrial furnaces.

Prevention against sulphurous emissions from these two types of fires is covered by two quite different procedures.

We have seen the rather illusory character of regulations and repressive measures against emissions from domestic fires. An effective struggle must be waged on the technical and economic level and by persuasion and active propaganda.

First, by means of a well-chosen price policy, operation of gas-fired domestic heating must be made cheaper than coal-fired installations. Recent discoveries of large deposits of natural gas may facilitate this.

Furthermore, the use of fuels containing more than

0·1–0·2 per cent sulphur in domestic fires and apartment heating plants will have to be forbidden in built-up areas (instead of 1·6 per cent authorised at present).

Finally, district-heating must be developed to the maximum. Steam generating stations which are able to use lower grade fuels such as coke, coal, domestic garbage, etc., fitted with gas cleaning equipment and restricted to zones as indicated above will have to be built on the outskirts.

Against industrial emissions, the existing regulations must be applied and the supervisory means of the Inspection des Etablissements Classés *must be developed in the private, public and semi-public sectors.* However, here we encounter economic difficulties. The economic operation of large industrial furnaces is dependent on the use of cheap fuels which have high ash and sulphur contents. If the emission of black smoke by these furnaces is limited (the fuel having been fully burned therein) it is difficult to avoid high concentrations of ash (pulverized-fuel-fired boilers) and oxides of sulphur. The trapping of these residues is often uneconomic owing to the enormous volumes of gas that have to be treated.

For these industries, the only effective and economic method seems to be zoning.

In fact, experience shows that beyond a certain safety perimeter (to be determined according to local geographic and meteorological conditions), emissions from large power stations, for example are diluted to such an extent that they can no longer cause any appreciable inconvenience to the population. Therefore, we should no longer see dwellings congregate in the immediate neighbourhood of these large industries. In our opinion bodies which construct such works should be obliged to purchase the safety perimeter which is scientifically recognized as adequate, around their installations. These bodies should also have to carry out adequate re-afforestation of this perimeter in order to facilitate permanent detection of the distribution of the nuisances around the plant by the behaviour of the vegetation and to trap dust and aerosols emitted, together with the well-known atmospheric purification effected by green belts.

Finally, as regards the pollution due to automobiles, the struggle must be carried out at technical level, both in the sense of total combustion of the fuel and in the arrangement of roads.

Improvement of total combustion will be obtained by encouraging research by car manufacturers on the lines of automatic carburettor regulation or perhaps in the use of injection engines as proposed by a large French firm. The solution to the problem raised by diesel engines which, when properly adjusted and not operated on overload, discharge neither fumes nor soot nor carbon monoxide, is strict enforcement of the regulations and prohibition of the use of gas oils containing more than 0·1–0·2 per cent sulphur. (Instead of the authorized 1·3 per cent).

As for two-stroke engines, it would be desirable for them to disappear from our towns because the very principle of their operation necessitates nearly all the lubricating oil being discharged into the air.

Trunk roads should be wide and planted with trees. The effectiveness of vegetation as dust precipitators needs no proof. Buildings thus withdrawn from the roads should be surrounded by as many gardens and open green spaces as possible.

While waiting for our towns to be rebuilt on these lines, a task which will take a long time and will be difficult but none-the-less possible provided the problem is tackled with foresight and courage, appreciable improvements would soon result, we say, by the widespread use of gas, sulphur-free petroleum products and district-heating in residential areas.

THE MEASUREMENT OF SULPHUR DIOXIDE IN THE ATMOSPHERE NEAR POWER STATIONS

W. G. CUMMINGS and M. W. REDFEARN, Central Electricity Research Laboratories, Great Britain.

SUMMARY: By means of instruments developed at the Central Electricity Research Laboratories it is now possible to make a realistic assessment of the contribution of a power station to the total sulphur dioxide pollution in a particular area and to estimate the efficiency of the dispersion of plumes from stacks under varying meteorological conditions. The methods employed to make best use of these instruments are described, together with some typical results.

Introduction

Modern power station stacks are designed to disperse the hot gases into the upper atmosphere so that, by the time the gases reach ground level, they are so diluted with air that the overall concentration of sulphur dioxide is low. The efficiency of a stack may be checked by measuring the concentration of sulphur dioxide in the atmosphere at ground level near the power station. However, as the sulphur dioxide concentration varies with the rate of emission of the gases from the stack and with changes in meteorological conditions it is possible that, although the mean concentration of sulphur dioxide is low, comparatively high sulphur dioxide concentrations may exist for short periods of time only.

For a realistic assessment of the degree of pollution, it is therefore necessary to measure the minute-to-minute variations in sulphur dioxide concentrations and at the request of a C.E.G.B. committee studying atmospheric pollution, an automatic sulphur dioxide recorder* and a portable meter* were developed[1], so that detailed sulphur dioxide studies could be made. With these instruments continuous readings are obtained in the range 0–50 p.p.h.m. sulphur dioxide with a sensitivity of 1 p.p.h.m. (1 part of sulphur dioxide in 100 million parts of air); the range can be extended but the sensitivity decreases in proportion to the increase in range. About twenty-five of each of these instruments are now in use near power stations in England and Wales and additional research equipment has been developed* for intensive studies of the dispersion of plumes from stacks.

This paper describes briefly the way in which these instruments are being used; the work is part of the atmospheric pollution programme of the Central Electricity Generating Board.

Survey Methods

Continuous Monitoring of Sulphur Dioxide Concentrations at Fixed Sites

For continuous monitoring of the sulphur dioxide concentration in the atmosphere near power stations the automatic recorder[1] is operated at a fixed site in conjunction with a wind speed and direction recorder. If two sulphur dioxide recorders are available they are placed so that, when wind blows from the power station to one recorder, the other is measuring the background sulphur dioxide being blown towards the station.

The continuous sulphur dioxide records are analysed by a method suggested by Lucas and Spurr[2]. The area with the sulphur dioxide recorder at its centre is divided into sectors (e.g. twelve 30° sectors, although they need not be equal) so arranged that the power station and other known sources of pollution lie near the middle of the sectors. The wind direction records are divided into corresponding sections so that, if the area has been divided into twelve sectors there are twelve fixed wind directions plus a calm section. Thus, with the power station in sector 1, when wind blows from direction 1, the sulphur dioxide recorded at the fixed site is the background concentration from sector 1 plus the sulphur dioxide from the power station.

The sulphur dioxide records are divided into levels viz. 0–1, 1–2, 2–4, 4–8, 8–16, etc. p.p.h.m. and the total number of hours for which each level occurred is obtained from the sulphur dioxide record chart for each fixed wind direction. This is done for one month at a time. The total number of hours for each sulphur dioxide level in each sector is then multiplied by the mean of each level to give a measure of pollution in sulphur dioxide hours. For example, assume that with the wind blowing from direction 10 the sulphur dioxide concentration was in the 2–4 level for a total of 5 hours and in the 4–8 level for a total of 2 hours. There would then be 15 SO_2 hr in the 2–4 level and 12 SO_2 hr in the 4–8 level, making a total pollution of 27 SO_2 hr for sector 10.

By entering these pollution values for each level and each sector in a table arranged as shown in Table I one obtains a picture of the total pollution at the fixed site, the pollution from each sector, the mean monthly concentration of sulphur dioxide at the site, the mean concentration arising from each sector and the length of time for which high levels of sulphur dioxide occurred. The results can also be correlated with station load and meteorological conditions.

Table I shows the results for 406 hours during February 1958 at a site in Bettws Village, South Wales, one mile east of a 120 MW power station. The power station is in sector 10 and its effect is clearly shown by the fact that in that sector there were 12·96 SO_2 hr pollution in the 8–16 p.p.h.m. level and 179·04 SO_2 hr in the 4–8 level. However, this means that the 8–16 p.p.h.m. level only lasted for a total time of one hour and the mean concentration of sulphur dioxide for the whole period was only 4·1 p.p.h.m. This is 2·7 p.p.h.m. higher than the lowest recorded for other sectors and 1·6 p.p.h.m. higher than the mean of the other sectors. The latter contain no sources of industrial pollution for some miles.

Analysing sulphur dioxide charts is tedious and time-consuming when done by inspection and a semi-automatic chart analyser, based on that designed at the D.S.I.R. Radio Research Station[3], has been developed for this work.

Rapid Measurements in a Selected Area

Much useful information can also be obtained by making rapid measurements at various points in a

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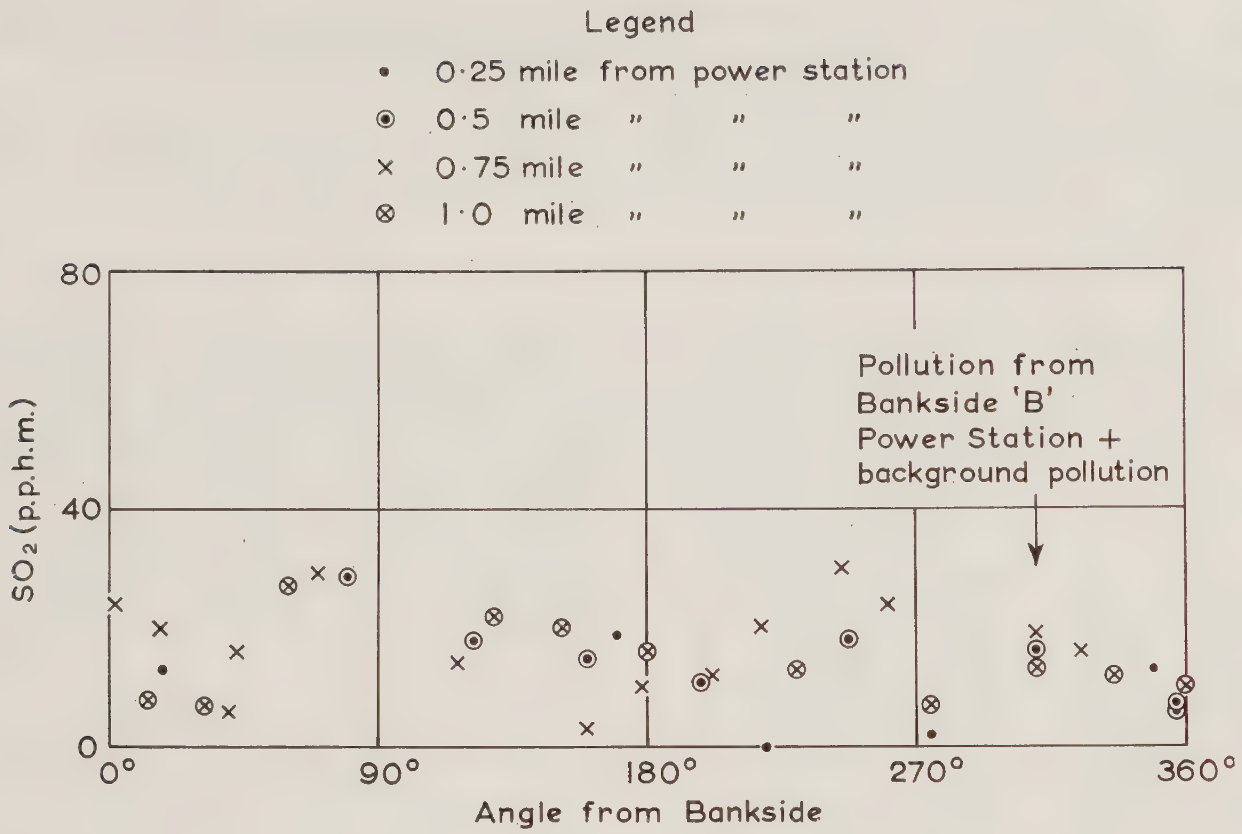
*Patent applications have been filed for the instruments described in this paper



selected area, and for this work, the battery-powered portable meter[1] is used in a small van or car.

Apart from investigating complaints of nuisance, surveys are carried out by making a series of measurements under different meteorological conditions at predetermined sites. The latter are selected on circles or arcs at distances of 0·25, 0·5, 0·75, 1·0, 1·5 and 2·0 miles from a power station or other selected point and the sulphur dioxide values obtained plotted against the compass bearing of the test site from the central point. Pollution greater than the background concentration shows up as peaks and, knowing the wind direction, the sources of pollution can be located. Figure 1 shows the pattern of pollution in the Bankside/St. Pauls area of London during the afternoon and evening of March 3, 1958.

It is also possible to estimate the width of plumes when they descend to ground level; on one occasion, near Earley Power Station, readings taken across the path of the plume 1·6 miles from the station rose from 0 to 8 p.p.h.m. and fell to 0 again over a distance of about 500 yards.

Sulphur Dioxide Telemeters

For intensive studies of the dispersion of plumes from stacks under rapidly varying meteorological conditions it is desirable to be able to measure sulphur dioxide concentrations simultaneously at various positions in a selected area. Sulphur dioxide telemeters which send their information by radio to a central point have been developed at the Central Electricity Research Laboratories[4] and are now being used in experiments to elucidate the behaviour of plumes under different meteorological conditions.

Air-borne Sulphur Dioxide Telemeter

The survey methods described so far give sulphur dioxide concentrations at ground level only. A sulphur dioxide telemeter weighing only 4 lb. including radio, blower, batteries and sufficient reagent for one hour's continuous operation[4] has also been developed at the Research Laboratories. It is carried by a tethered hydrogen-filled balloon in experiments to determine the cross-sectional area of a plume at increasing distances from a stack. It is also possible to study the distribution of sulphur dioxide at increasing heights above the ground, e.g. during periods of smog.

Conclusions

Automatic recorders, portable meters and ground-level and air-borne telemeters specially designed for the measurement of small quantities of sulphur dioxide in the atmosphere are being used by the Central Electricity Generating Board for organized surveys of the sulphur dioxide levels near power stations and for research on the dispersion of plumes from stacks.

Realistic assessments are now being made of the degree of sulphur dioxide pollution caused by power stations and it has been found that the high stacks of modern power stations disperse hot gases so effectively that the concentration of sulphur dioxide in the atmosphere at ground-level near the station rarely exceeds 30 p.p.h.m. Moreover it has been shown that the maximum values occur for short periods of time only. The mean concentration of sulphur dioxide at any point near a modern power station is much lower than 30 p.p.h.m. and a two-year survey near a power station in Wales showed that the mean concentration for the whole of the period was less than 5 p.p.h.m. In large towns the *mean* concentration of sulphur dioxide can exceed 30 p.p.h.m.

From studies of plume behaviour under specific conditions, simplified formulae are being prepared for the dispersion of plumes from stacks; these will be useful to stack designers.

Acknowledgements

The authors would like to thank Dr. J. S. Forrest, Director of the Central Electricity Research Laboratories, for permission to publish this paper.

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[4] To be published shortly.

Table I

PRESENTATION OF AN ANALYSIS OF SULPHUR DIOXIDE RECORDS

Results for Bettws Village, February 1958

SO_2 *level (pphm)*	*Pollution (SO_2 Hours) i.e. Product of concn. and no. of hours within the given levels and given wind sectors*														*% Total polln in each range* $\left(=\frac{C \times 100}{Y}\right)$
	Wind Sector														
	1	2	3	4	5	6	7	8	9	10	11	12	*Calm*	*Totals (=C)*	
0– 2	3·64	2·56	0·21	8·98	11·93	10·87	8·30	15·62	24·80	8·19	3·03	4·91	21·72	124·76	10·24
2– 4	7·17	25·32	0·18	48·78	41·13	5·58	8·58	20·07	150·45	107·76	47·10	9·36	128·55	600·03	49·25
4– 8	9·12	9·72	—	39·06	20·64	6·48	13·26	52·68	68·88	179·04	64·44	2·52	14·52	480·36	39·42
8–16	—	0·32	—	—	—	—	—	—	—	12·96	—	—	—	13·28	1·09
16–24	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Total polln in sector (=B)	19·93	37·92	0·39	96·82	73·70	22·93	30·14	88·37	244·13	307·95	114·57	16·79	164·79	1,218·43† Y	
% Total polln $\left(=\frac{B \times 100}{Y}\right)$ ...	1·64	3·11	0·03	7·95	6·05	1·88	2·47	7·25	20·04	25·27	9·40	1·38	13·53		
Mean concn while wind is in sector $\left(=\frac{B}{A}\right)$	2·64	3·00	1·44	3·05	2·53	1·66	2·25	2·84	2·82	4·10	3·89	1·99	2·46		
Mean concn weighted for wind frequency $\left(=\frac{B}{X}\right)$	0·05	0·09	0·00	0·24	0·18	0·06	0·07	0·22	0·60	0·76	0·28	0·04	0·41	3·00*	

* Mean monthly concn SO_2 for site (pphm)
† Total pollution for the month at the site (SO_2 hr)
A = Total hours for each wind direction
X = Total hours of record
Y = Total pollution (SO_2 hrs)

RESEARCHES ON THE ATMOSPHERIC POLLUTION OF THE CITY OF MILAN

A. GIOVANARDI, E. Grosso and E. De Fraja Frangipane (Institute of Hygiene, University of Milan; Institute of Sanitary Engineering and Polytechnics, Milan).

SUMMARY: A programme of air pollution measurement has been carried out in Milan over the last three years, measuring deposited matter, suspended matter, and sulphur dioxide (using the lead peroxide method). Twelve permanent stations have been used, plus extemporaneous measurements at other sites in the streets. It is concluded that badly run domestic heating systems are a greater cause of pollution during the winter than either vehicles or industry.

Since the beginning of 1956, the Hygiene Institute of Milan University has been carrying out a programme expressly concerned with a series of investigations to establish the causes and the nature of atmospheric pollution in this city and in some neighbouring centres (Sesto San Giovanni, Pero, etc.). These are being made with the co-operation of the Hygiene Office of the Milan Municipality and of the Sanitary Engineering Institute of the Milan Engineering School. Such investigations are carried out in 12 permanent stations situated in the residential and industrial areas and in the form of *extemporary determinations* in different sites in suitably chosen city streets. The data collected and the observations made from 1956 to 1958 show the following data as to the behaviour of the main pollution indexes:

(a) the highest values of *deposited matter* were shown during winter in the residential areas of the city centre (maximal value = 12·50 ton/Km²/month at the station of Milan centre in winter 1956) and the lowest ones in summer (minimal value = 4·02 ton/Km²/month at the Melegnano station in summer 1956) without important differences within residential areas and more or less industrialized peripheral areas of the city and of the suburbs (Sesto San Giovanni, Pero, etc.);

(b) the total *undissolved matter, solid matter soluble in* CS_2 and *oombustible matter* showed a seasonal behaviour substantially like that of the *deposited matter*, with an excess of the winter values compared with the summer values usually apparent in the residential areas of the city centre;

(c) the *undissolved matter* collected in winter in the residential areas appeared to be composed of about 61 per cent combustible matter, and about 37 per cent ash; whilst the undissolved matter of the industrial areas contain about 62 per cent of ash and 35–37 per cent of combustible matter; in summer the undissolved matter of the residential areas and of the more or less industrialized areas have mainly shown the same composition;

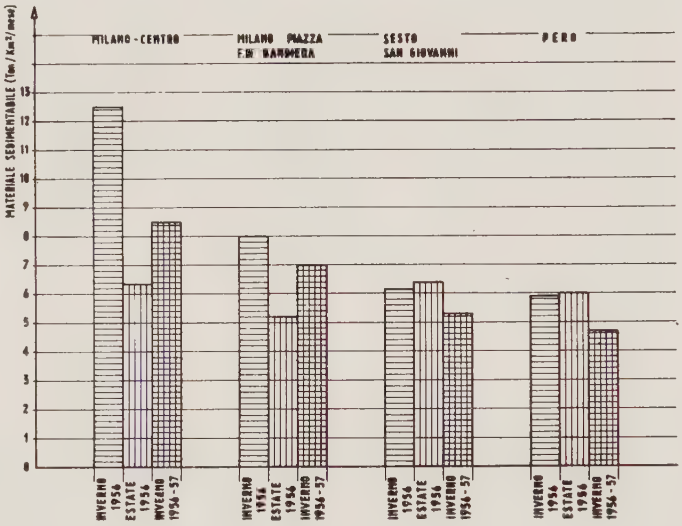

Fig. 1. Behaviour of the deposited matter (ton/Km²/ month) in the stations of Milano-Centre, Milano-Piazza Fratelli Bandiera, Sesto San Giovanni and Pero in winter and summer 1956 *and in winter* 1956-1957.

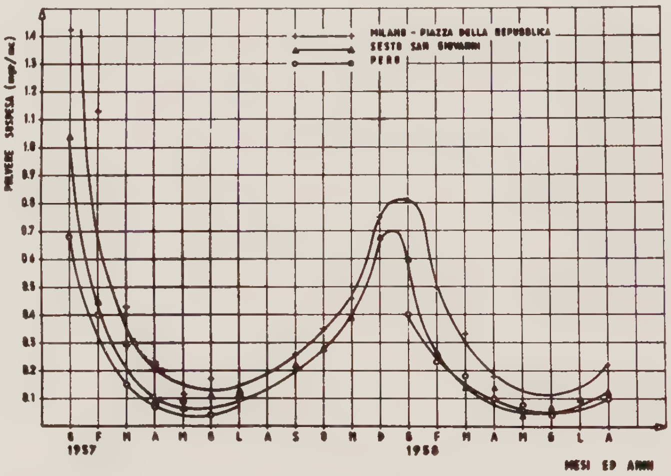

Fig. 2. Behaviour of the suspended matter as average daily value (in mgr./mc) in the stations of Milano-Piazza della Repubblica (Station A), Sesto San Giovanni and Pero in January 1957 *and August* 1958.

(d) similar to the deposited matter (as to the seasonal variations and the differences within residential and industrial areas) was the behaviour of two other indexes of the combustion process, the *suspended impurity* determined by filtering a measured volume of air through a white filter paper and matching the grey stain left on the paper with a scale of shades previously calibrated, and the sulphur dioxide determined with the lead peroxide instrument. The highest values of suspended impurities were observed during the winter in the residential areas (maximal value = 0·997 mgr/mc at the station Milan-Piazza della Repubblica, in winter 1957, whilst the lowest ones were noticed in summer without any sensible differences within residential and more or less industrialized areas (minimal value = 0·073 mgr/mc at the Pero station in summer 1958);

(e) on examination of the dust particle size, the suspended impurities showed during winter to contain for the most part (up to 89 per cent) particles with a diameter lower than 1 micron, constituted of coal and ash;

(f) by extemporary determinations the highest sulphur dioxide concentrations (up to 0·530 ppm) have been made evident in the residential areas during winter, early in the morning;

(g) the highest *sulphur dioxide concentrations as a mean daily value* were observed everywhere during winter

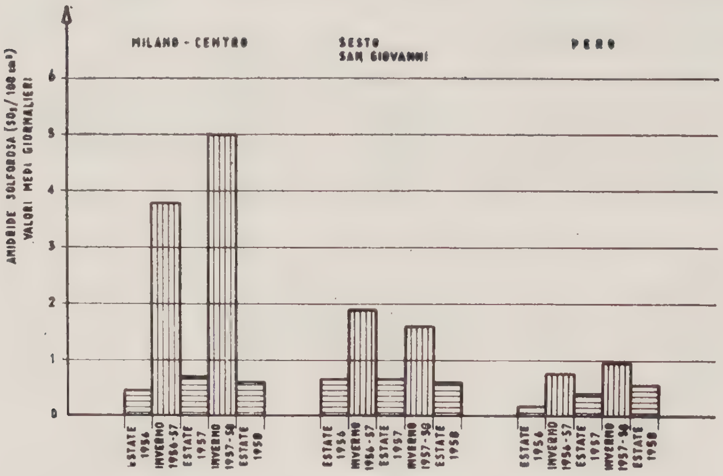

Fig. 3. Seasonal behaviour of sulphur dioxide (determined by the lead peroxide method) in the stations of Milano-Centre, Sesto San Giovanni and Pero. Average daily values (in mg. SO_3*/100 cm*^{2}*).*

with a slight prevalence at the station of Pero (the area of refineries and chemical industries);

(h) special determinations (of deposited matter, suspended impurity, and sulphur dioxide instituted for comparison in two stations placed at different heights in a dominantly residential area of the city (" grattacielo di Piazza della Repubblica "), the one at a height (from the ground) of 33 m and the other at 104 m, showed that the lower atmosphere layers are more polluted than the higher ones;

(i) the more or less abundant rainfall regularly gave rise to a more or less sensible reduction of *the air-dust content* (up to one-third of the values concerning the clear days); the fog, on the contrary, regularly caused an increase of the same;

(j) at some places in the city streets notably congested by traffic (crossings, tunnels) and in the hours in which it was most dense, a series of suitable determinations did not show carbon monoxide concentrations higher than 62 ppm;

(k) by the investigations carried out to the present time in the residential areas of the city (centre and near neighbourhoods), pollutants of industrial origin (chlorine, fluorine) were never found or they were detected at notably low concentrations (ammonia, nitrogen oxides), far from the bounds considered as toxic in industry; also in the more or less industrialized peripheral areas and in the suburbs the pollutants, also of industrial origin, were made evident at rather low concentrations (except the particular case of an enamel-varnish industry in the neighbourhood, from which fluorine was found at concentrations of 0·076–0·043 ppm.

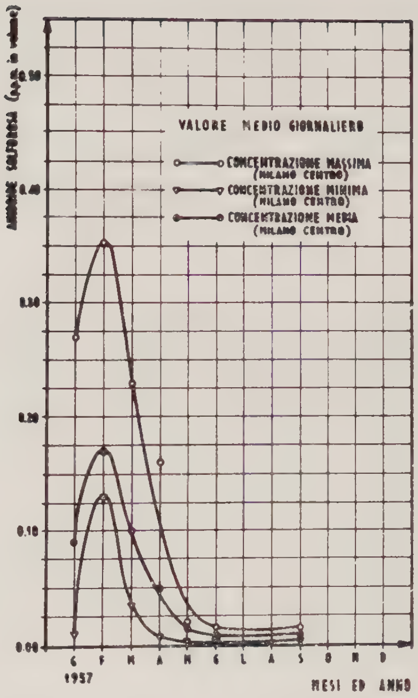

Fig. 4. Behaviour of sulphur dioxide as average daily value. Maximum, minimum and average concentrations (in volume p.p.m.) observed in the station of Milano-Centre from January to June 1957.

To conclude, these researches, which have lasted for three years, particularly on the ground, of the behaviour of deposited matter, suspended impurity and sulphur dioxide, show that *domestic combustion (from heating plants) badly conducted, represent, during winter, the main cause of air pollution in Milan; and that in this direction it seems that, particular cases excepted, lesser importance is to be ascribed to vehicular traffic and manufacturing industry.*

MONITORING FLUE DUST SURFACE AREA

D. H. GRINDELL, Ph.D., B.Sc.(Eng.), Research Laboratory, The British Thomson-Houston Co. Ltd., Great Britain.

SUMMARY: The air pollution characteristics of flue dust are governed mainly by the size range of the particles, rather than with factors as opacity and gross weight. An instrument, working on the principle of the electrostatic precipitator, has been developed, which records the surface area of dust sampled. It is sensitive to small as well as large particles.

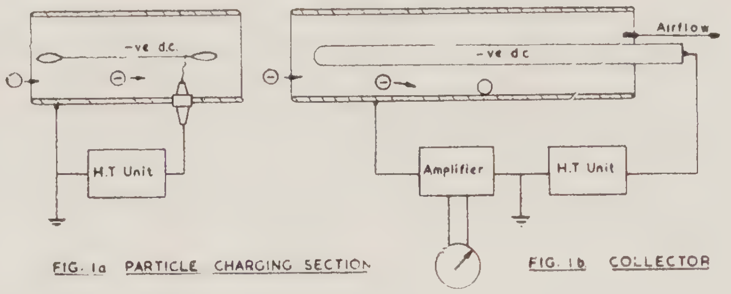

FIG. 1a PARTICLE CHARGING SECTION FIG. 1b COLLECTOR

SIMPLE DUST MONITOR

The opacity of a chimney discharge measured by light-obscuration instruments, the gross weight of solid particles determined, often tediously, by gas filtering and smoke darkness defined by the Ringelmann Scale, are not strictly factors of primary importance in the study of air pollution, for they are not directly related either to its basic characteristics or to its most serious consequences. The dispersion of airborne particles, their fog-inducing tendencies and their detrimental effects upon health are governed more by the size distribution, surface area and fundamental chemical and physical properties of the impurities.

Smoke and dust particles within the range 0·1–1·0 microns diameter are largely responsible for the formation of industrial fogs, as well as being pathologically the most dangerous, but since they are also comparable in size with the wavelength of visible light, the true meaning of optical measurements of their concentration may be obscure.

Recent work by the British Thomson-Houston Co. Ltd., has resulted in the development of an electrostatic dust monitor which records the surface area of dust sampled per second and is equally sensitive to these small particles. The equipment was primarily developed for use in power station boiler installations, but the method is applicable to other gas-entrained dusts, smokes and certain fumes.

The working principles are similar to those of the electrostatic precipitator, such as that outlined in Figure 1(a) comprising an earthed metal tube surrounding a thin axial wire to which a high voltage is applied so that the air inside is ionized and a corona discharge is established.

Dust present in this inter-electrode gap is bombarded by gas ions and each particle rapidly acquires an electric charge approximately proportional to the square of its radius.

In the precipitator, dust, once charged, is attracted to the outer tube; in the dust monitor, the velocity of the stream carrying the dust and the length of the corona wire are adjusted to ensure that precipitation occurs in a separate collecting section, the outer cylinder of which is connected to an amplifier, and the long central electrode is corona-free and charged to the same polarity as the dust, as shown in Figure 1(b). The flow of charged dust particles to the outer tube constitutes a current proportional to the total

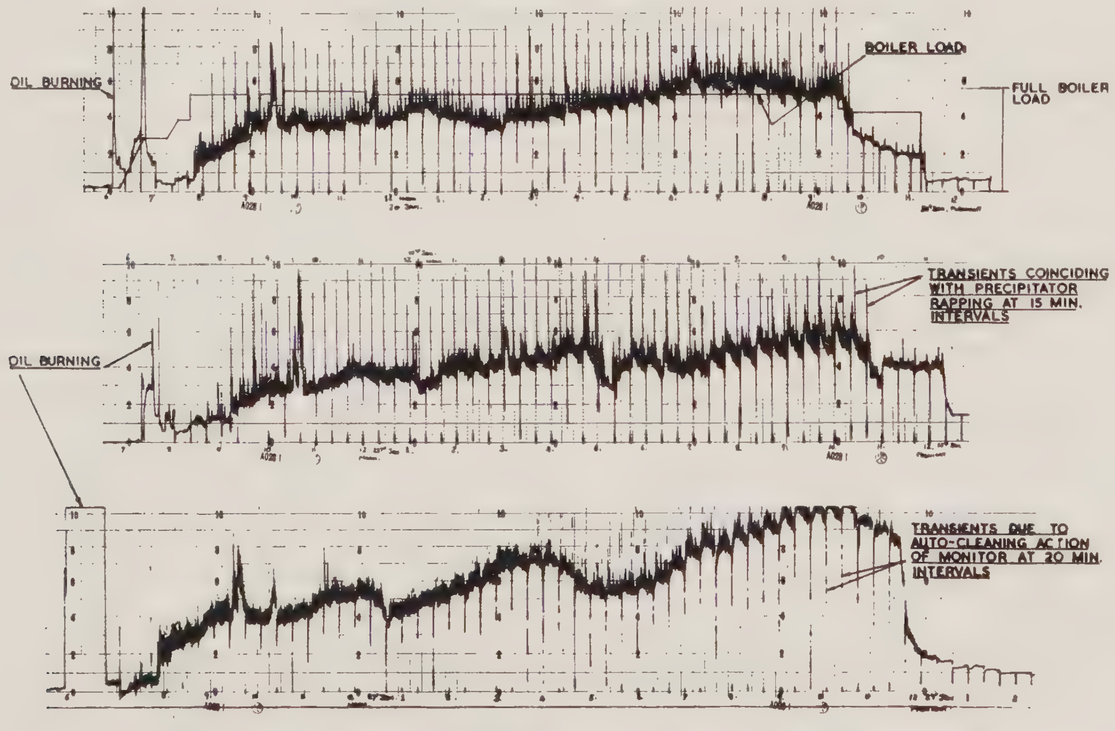

FIG. 2 RECORDINGS BY THE ELECTROSTATIC DUST MONITOR OF ASH SURFACE AREA PER SECOND IN FLUE GASES LEAVING THE PRECIPITATORS IN A PULVERISED-FUEL-FIRED BOILER INSTALLATION.
ON EACH OF THESE THREE WEEKDAYS THE BOILER STARTED UP ON FUEL OIL IN THE MORNING AND CLOSED DOWN AT ABOUT MIDNIGHT

external surface area of the dust sampled by the monitor per second.

The practical dust monitor is fitted through the flue duct wall with sampling and return pipes projecting into the gas stream. Irrespective of velocity, an isokinetic and representative fraction of the main gas flow is maintained through the apparatus and by careful aerodynamic considerations, a driving fan is unnecessary. Electrical heating is provided to prevent condensation of the hot gases and, to reduce dust build-up, automatic self-cleaning by a periodic air-blast is incorporated, atmospheric air being used for this purpose in installations where the duct pressure is negative.

With the co-operation of the Central Electricity Generating Boad, experimental monitoring equipment based on these principles has been installed on the outlet side of the dust arresting plant of an Electricity Generating Station burning pulverized fuel and has now been operating satisfactorily for some months. Prototype models will shortly be on trial at stations with different boiler characteristics.

Typical recordings are reproduced in Figure 2· The transients at 15 minute intervals are due to rapping in the main precipitator; those at periods of 20 minutes are due to the monitor self-cleaning action.

When the boiler is started up on fuel-oil, the flue gases contain a large number of fine particles. These are often recorded on the chart as an off-scale reading which persists until the changeover to pulverized fuel is made.

Unless an arbitrary system of units is desired, the reading of current (1 mA full scale on the chart) may be converted by calculation to surface area of dust passing each square foot of chimney duct per second. This is done in terms of the amplifier gain, the corona current and particle dielectric constant. The latter does not vary significantly for pulverized fuel ash and since it does not affect the reading directly, a single determination suffices.

Alternatively, the apparatus is calibrated against the weight of dust per unit volume of gas determined by a gas-filtering technique. This requires the mean monitor reading during a three or four hour period under constant boiler conditions, measurement of the flue gas duct velocity and specific surface area (cm^2/g) of a typical dust sample.

IV. 45

RESEARCH ON AIR POLLUTION IN SOUTH AFRICA

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SUMMARY: Air pollution in South Africa has grown rapidly since 1930. Preliminary research has been carried out, using British pattern instruments. Results show that pollution levels in large towns in the Union are comparable with pollution in English towns. As a result of increased interest, wider research projects should be possible.

South Africa is a rapidly growing country both in the size of its cities and the extent of its industrialization. As a result, while the pollution of city air in 1930 was virtually negligible, by 1950 smoke at any rate had become a marked threat to the amenities of several cities and sulphur dioxide damage was easily detected. However, it was still possible to dispute the acuteness of the situation and while scientists who were aware of the air pollution problems of the industrialized countries of the world wished to undertake research upon the problem in South Africa, administrative bodies were not so alive to the situation and as a result it was not possible to find funds for a large scale research project.

It was considered in 1954 that such a situation should not prevent a start being made upon a study of air pollution for it was realized that the results of a limited research could be of value in the education of the public and that an educated public would be more willing to support an enlarged research project. The National Physical Research Laboratory therefore, embarked upon a study of smoke and sulphur dioxide concentrations in Pretoria, the administrative capital of South Africa, and made use of the type of equipment which was developed in England for this purpose. This apparatus draws air through a filter paper and then through a wash-bottle filled with a dilute solution of hydrogen peroxide, the volume of the air being measured with a commercial gas meter. Only six monitoring stations were used and at first they were closely spaced across the centre of the city. When it had been established that there were no marked variations of pollution concentrations over short distances in the central area, the alternate stations were closed down, the apparatus being moved to positions in the suburbs of the city. In this way a small group of stations was made to serve a wider area than might have been thought possible and a considerable volume of information has been obtained. In addition, deposit gauges were used to assess the mass of heavy material deposited on exposed surfaces and two papers have been published so far upon the findings of four years of investigation.[1, 2] It was soon shown that the pattern of pollution was very much what would be expected in the light of such city surveys as the Leicester study or the sootfall survey made in New York. The pollution concentration was highest in the centre of the city and fell off as one moved away from the centre. It reached a maximum in the winter and a minimum in the summer. There were signs of a reduction of concentration during the week-ends, indicating the extent to which industry was a source of pollution, and from this and other information it was deduced that the contribution to the smoke of the city, by domestic and semi-domestic users of coal was probably in the region of 50 per cent of the total measured. It was also shown that over a period of four years there was a steady increase in the level of the pollution as a result of the increase in the population and the increased use of coal.

In 1957 and 1958, first the city of Durban and then the cities of Johannesburg and East London embarked upon similar programmes of measurement and their observations were collected and analyzed at the National Physical Research Laboratory. The figures show that the smokiness of these four towns (out of the eight larger towns of the Union) is by no means slight and that in Pretoria and Johannesburg smoke concentrations are observed which are roughly comparable with concentrations observed in Ilford, Leicester, Portsmouth and Southampton. Table I gives the figures and although it may be objected that the values for the English towns, as taken from the D.S.I.R. monthly reports, may not represent the whole of each town in the same way as the South African figures represent the South African towns, nevertheless it remains that somewhere in the South African towns there are conditions somewhat similar to those experienced somewhere in the English towns.

During 1959 an attempt was made to study the concentration of ozone and other oxidizing chemical radicles in the air of Pretoria. Not many opportunities were found for carrying out such experiments but it was found on those occasions that ozone concentrations were low although petrol consumption in Pretoria is relatively high. In fact, the consumption of petrol per day per square mile of the city is about one-third of the corresponding figure computed for Los Angeles, though of course the total petrol consumption for the town is very much smaller than it is in Los Angeles County. This low figure for ozone can be linked with the high figure for sulphur dioxide, in agreement with the suggestion by Cholak[3, 4] that high figures for the reducing agent sulphur dioxide must necessarily go with low figures for the oxidizing agent ozone.

A start has been made with a study of the structure of the atmosphere up to a height of 800 ft above the ground. Temperature profiles have been constructed for all periods of the day and night, and it has been shown that during the later periods of the night there is, in winter, a fairly regular occurrence of a very steep inversion gradient in the first 200 ft of height followed by an isothermal layer extending from the 200 to the 800 ft level. This condition was postulated by the investigators of the Trail smelter in Canada in 1940 to account for the sudden appearance of sulphur dioxide at places over 20 miles apart at the same time in the morning.[5] It was thought that heating of one side of a valley by the rising sun before the other side received the sunlight caused a convection current to overturn the upper layers, bringing the sulphur dioxide in the isothermal layer down to the ground. No signs of such a process have been observed during the present measurements but the existence of the layer has been clearly shown.

Proposed work for the future

As a result of heightened interest in air pollution it should be possible in the near future to conduct a

Table I

Towns	*Smoke mg/m^3*		*Sulphur Dioxide mg/m^3*		*Total Insol. Deposit gm/month on bowl*	
	Summer	*Winter*	*Summer*	*Winter*	*Summer*	*Winter*
Pretoria, 1955/58	·108	·200	·087	·106	·27	·27
Johannesburg, whole town average	·124	·321	·174	·154	·15	·30
Durban	·121	·174	·032	·057	·36	·28
East London	·114	·154	·287	·205	·38	·24
Ilford	·07	·29	·09	·20	·12	·18
Leicester	·06	·13	·09	·18	·14	·20
Portsmouth...	·06	·26	·04	·08	—	—
Southampton	·04	·17	·05	·11	·08	·09
London: Kensington	·12	·24	·15	·48	·22	·28
St. Pancras	·16	·30	·20	·31	·21	·24

more extended study of pollutants in the atmosphere. The programme is planned to involve physical, chemical and industrio-economic aspects. Biological aspects may be considered later. It is proposed to extend the city surveys to include those cities which still have no measuring programme. It is also proposed to make a chemical study of the constituents of air pollutants in various cities and to correlate the quantitative information with the information available from the city monitoring stations, of the general level of pollution at the time.

A third line of activity will be a full study of the micrometeorology of various sites in South Africa, for the purpose of obtaining information which may be used in industrial siting and in giving advice on such questions as optimum stack height for good diffusions of effluent. Already the department is being asked to assist developing industries in such matters and basic information on atmospheric structure will be of assistance in such work. Coupled with this investigation will be fundamental studies of the physical processes involved in the diffusion of pollutants. A fourth project involves a study of the quantities of coal used by different types of coal purchasers in the larger cities of South Africa. This will be used in an analysis to supply the data upon which an industrial programme for the supply of smokeless fuels can be based. The study will supply figures for the potential market for such fuels and also for the haulage distances—and costs—which will be involved. This is a type of study which is perhaps peculiar to South Africa, because in the Union there is not available a wide range of fuels alternative to coal, as is the case in England. For a reduction of smoke emission to be possible therefore, new industries must be created and these industries must know the potential market before they start. Thus the last project of the research programme has the very practical aim of paving the way for the introduction of legislation for the reduction of air pollution.

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CONTRIBUTIONS TO THE "SMOG" PROBLEM

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SUMMARY: Smog is a synergistic effect of dust or soot and H_2SO_4. As it is at present not possible to remove the large quantities of sulphur oxides, attention should be given in combustion processes to the emission of a minimum of soot and dust into the atmosphere. As the appearance of one of the synergists is reduced, one may expect a reduction in smog-poison.

Smog has been known for 80 years as the cause of damage to health. It occurs in London particularly where large quantities of coal are burned in a small area. The remedy for such airborne intoxication of the population is only possible by comparative epidemiological investigations and measurement of the immission.

In the following lines under "A" an attempt is made to assess the aetiological significance of the epidemiological and chemical results recorded in the literature. In Section B my own quantitative observations are described in a field which does not show any morbidity caused by smog, but the observations make it possible to assess the behaviour of sulphur dioxide in comparison with dust.

A. Survey of the Literature

The danger of damage and disease by smog rises (a) with the duration of residence in a smog area[1], (b) with age[2], (c) with the density of population and (d) with the rise of SO_2 above 0·3 ppm and of smoke above 0·6 mg/m^3 in London[3].

The results for (c) and (d) are similar to rise in mortality of neoplasmas of the respiratory ducts; for the large cities in U.S.A. this has been proved to be a function of high population density[4] and industrialization[5]. It has been proved statistically. The compound responsible, benzpyrene, is also found in effluent gases. Damage having been caused in the endemic districts, the disease may manifest itself after many years, as the excessive mortality of English immigrants in Australia shows. This is a parallel to (a). A similar relationship is known for silicosis where the onset of the disease depends on the dust content of the air and on the duration of activity in a dusty atmosphere.

As noxious substances causing smog disease must be considered[6]: (1) SO_2 dissolved in fog; (2) SO_2 absorbed on dust; (3) the synergic effect of certain substances.

Regarding (1): as the MAC*-value for $SO_2 =$ 5 ppm (formerly 10 ppm), this gas may probably be excluded as a causative agent.

Regarding (2): experiments[7] with SO_2 adsorbates on soot show only small effects in animal experiments.

Regarding (3): many facts indicate a synergic effect of dust or soot which is loaded with sulphuric acid. This is indicated by:

Sulphuric acid as effective substance

Even 0·5 mg/m^3 increase breathing rates[8], in man 2 mg/m^3 caused persistent bronchitis[9], whereby particles of 2·5 micron reached the bronchi and of 0·8 micron the alveoli[10]. The conversion of SO_2 into SO_3 is possible in a *moist* atmosphere[11]; the proportion of SO_3 is said to rise thereby from 3·3 per cent, as it occurs in smoke, after 7 hrs fog to 20–24 per cent, after 11 hrs to 30 per cent. This increase is understandable, for coal smoke contains, i.e. Fe_2O_3, oil smoke V_2O_5 and NiO, i.e. catalysts which promote the oxidation of SO_2. My own examination of soot from combustion showed for coal soot 6 per cent H_2SO_4, 35·2 per cent ash, the latter with 94 per cent Fe_2O_3; pH of the water soluble in 2 per cent 1·51. Oil soot 12·3 per cent H_2SO_4, 16·8 per cent ash, the latter with 30 per cent Fe_2O_3, 8 per cent CaO, 2 per cent NiO; the 2 per cent aqueous solution = pH 0·86. Another oil soot from a roof gutter of a fuel oil installation with oil of 2·6 per cent sulphur content gave 7·6 per cent H_2SO_4 and 10·6 per cent HSO_4, mostly as sodium salt. The water content of both kinds of soot was below 1 per cent, showing the high concentration of H_2SO_4, being perhaps 80 per cent and causing corrosion. This was found in roof gutters and on parked motor vehicles.

Dust as Active Agent

Extensive investigations with the electron microscope of inhaled and exhaled aerial dust[12] have shown that only particles of 0·25 to 10 micron reach the alveoli, but that only 85–98 per cent of these are deposited there. Aerosols may absorb pollutants and increase their effect on the lungs; paraffins are among the promoters of this effect[13 14]. In order to avoid changes of the dust in dust filters, aerosols should be obtained with the aerosol spectrometer by Goetz.

All these facts indicate that the smoke emitted from the chimney already possesses toxic properties. Further, fog produced under high pressure weather conditions will lead to a gradual loading of the condensation nuclei with SO_2, for in air of 65 per cent saturation these carry a coating of water[15]. Thus a washing out of SO_2 from air on to the fog particles will occur. Rain washes the SO_3 aerosol better than SO_2[11]. The SO_2 adsorbed by aerosols and then oxidized will be as toxic as chimney smoke, but will be even more so as it enters the lungs more readily. After inhalation of SO_2[15] the maximum of activity in blood is reached after 3 hrs and decreases after 24 hrs to 30 per cent, but in the lung the activity remains unchanged for several days[16]. Therefore, the specially toxic soot—H_2SO_4—aerosols remain for a long time in the most sensitive lung tissues.

Measurements in the City of Hamburg

For the control of air pollution and the measurement of soot concentration in the air in the different districts of the city a net of observing and recording stations was established in Hamburg five years ago. An "Avigraph" worked out at the Hygiene Institute of Hamburg sucks the air through a nozzle[17]; the dust hits a sticky paper and by its impact remains on it. The number of particles compared with blacking is well known by many measurements with the Zeiss Konimeter. Every half hour throughout the day the intensity is visually measured in comparison with standards. During the last year SO_2 and SO_3 were also measured with the Autometer of Woesthoff. These are intended to give information regarding the possibility of damage to man and plants by city air.

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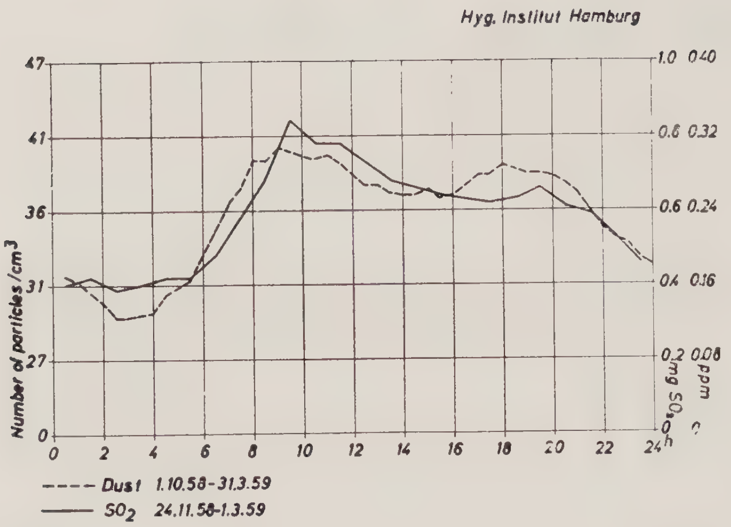
* Maximum allowable concentration.



In order to judge the measurements of extreme weather conditions the variation of dust and gas must be known for the hours of the day and the days of the week.

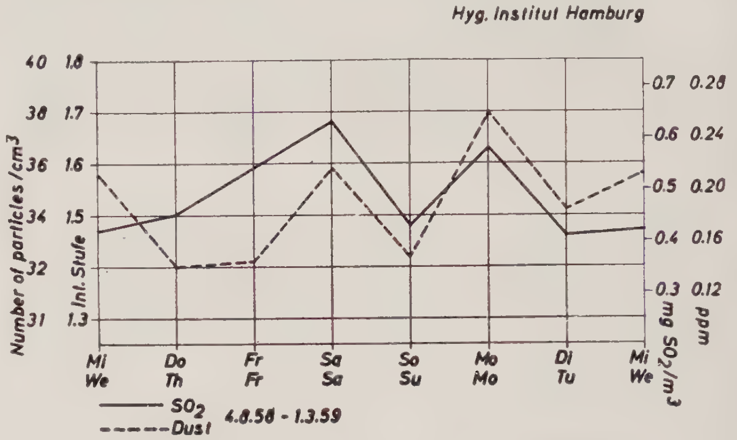
In Fig. 1 the daily and hourly means are shown for winter six months 1958, the observing station being 25 m above the ground. The small discrepancies in the run of SO_2 and dust is probably due to street traffic. The form of the curve has been known for a long time. In former investigations[18] at the same station the diurnal peaks of dust content were obtained for individual seasons. They were found for May–July at 6.30, 20.30 o'clock, for August–October 8–9.00, 18–20.00, for February–April at 9.00, 18–19.00 for November–January 10.00, 16–17.00. The effect of radiation upon turbulence is shown very clearly.

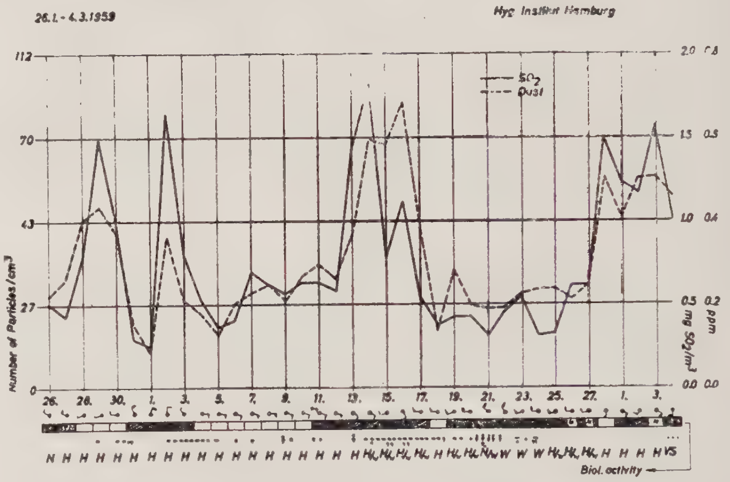
Fig. 2 shows the run for weekdays as the mean of the period August 1958–February 1959. It is striking to note the strong rise of SO_2 on Mondays and the low dust content in mid-week. During that period the mean value for SO_2 was 0·2 ppm, similar to that in London 1955/56.

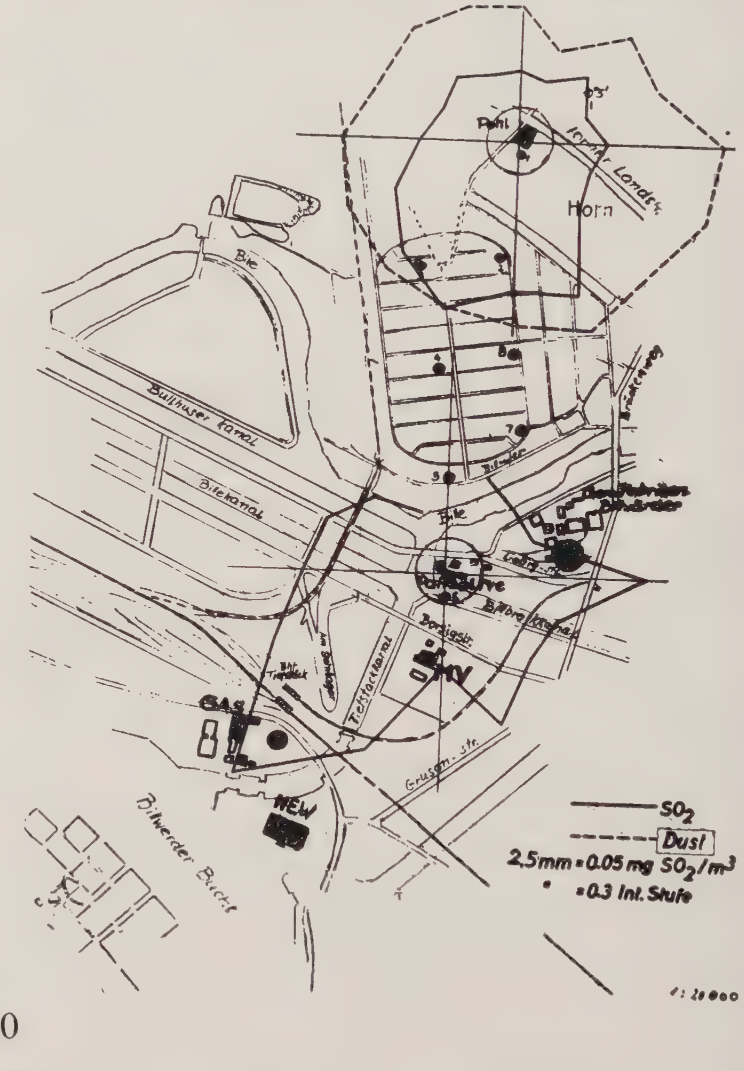
Fig. 3 is intended to show the effect of the emissions of an industrial area upon the neighbouring residential area. In the south-west of the lower observation point is situated a sulphuric acid works, a gas works and electric power station. The higher observation point 1·55 km distant shows the SO_2 effect already considerably rounded off, probably by reason of the diffusion of the gas. The outer hatched curve represents the dust-windrose, also obtained by evaluation of the intensities according to direction and duration of the wind during six months.

In Fig. 4 are shown the daily means for dust and SO_2 from January 26–March 4, 1959, at the same observation point as for Figs. 1 and 2. In addition the weather data are given and the biotropic irritation force of the weather conditions according to information by the Meteorological Office, Hamburg. The period February 13–17 should be particularly noted: SO_2 gets ahead of the dust; on February 15, a Sunday, it drops from 1·8–0·78 mg/m³, probably on account of adsorption of SO_2. According to Fig. 2 one would have expected a drop to 1·2 mg/m³ only. The peak of the dust arrives only two days after that of the SO_2. In these foggy days many people experienced for the first time the sensation of asthmatic breathing difficulties on their way home from work. A smell of SO_2 could not be observed, although workers in experimental rooms could recognize 0·5 mg/m³ SO_2 quite readily.

Mortality through bronchitis and pneumonia did not rise during the foggy days. The average deaths per week in Hamburg caused by these diseases was 3·7 and 13 respectively during November 1958–February 1959. During the four weeks following January 25, 1959, the number of deaths were 5, 2, 1, 5, respectively (3 of the last 5 in outer districts); by pneumonia 19, 11, 7, 6. From these figures it must be concluded that the prior pollution of the air in Hamburg is apparently so small that it does not cause any liability to respiratory diseases such as the smog disease.







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From following paper, No. 47, Research and Investigation in Japan

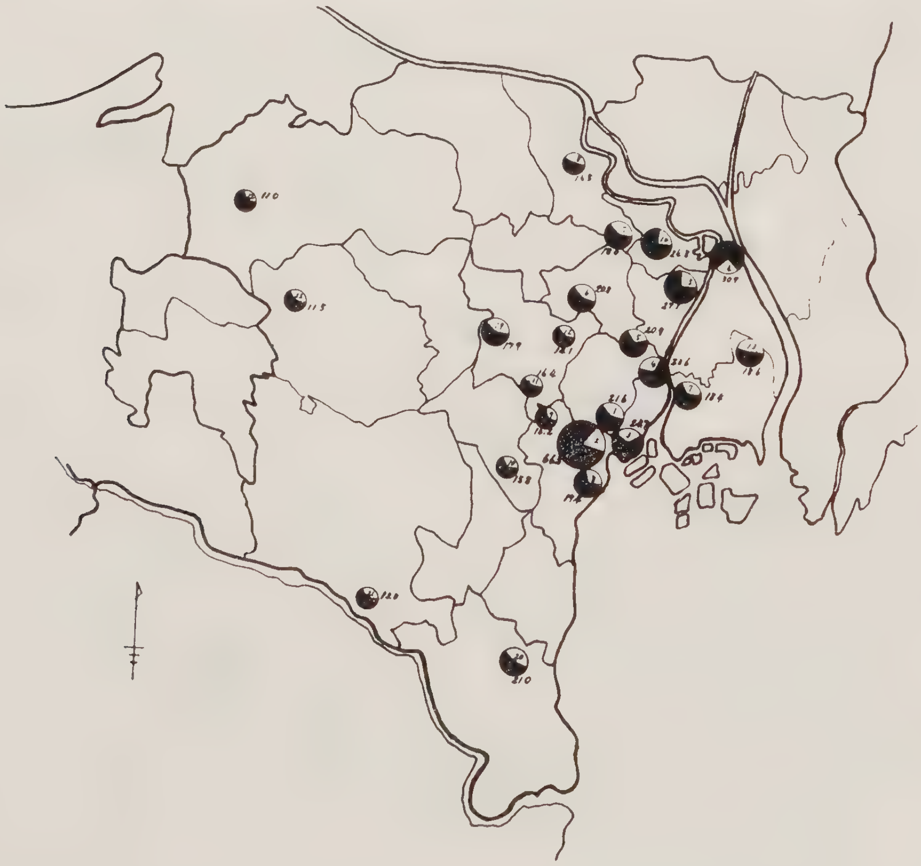

Fig. 1. City of Tokyo, Monthly mean distribution of deposited matter, tons per sq. km. per month.

RESEARCH AND INVESTIGATION IN JAPAN

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SUMMARY: Recent research and investigation relating to air pollution is carried out by local governments or local research commissions in the prefectures and cities. The various types of research undertaken are outlined. Since 1950 the number of reports on air pollution made public has gradually increased. A number of diagrams are given showing the weight of deposited matter in major industrial districts and cities. Differences in pollution between the different parts of cities show the principal source of pollution was industry. A list is given of the liaison organizations for expediting research and investigation.

The scope of recent research and investigation relating to air pollution is that carried out by the local governments themselves, or local research commissions in the prefectures and cities, i.e. Sapporo-Shi, Tokyo-To, Kanagawa-Ken, Osaki-Shi, Amagasaki-Shi, Kobe-Shi, Ube-Shi, and Fukuoka-Ken. It covers measurement of the volume of falling soot and density of sulphurous acid gas; detection of the relation between air pollution and meteorological conditions; meteorological survey of air pollution; study of measuring methods for air pollution; research into the influence of air pollution on vegetables and on human bodies.

Since 1950 the reports on air pollution made public in the academic societies of health, meteorology and chemistry, have gradually increased in number. The attached diagrams shows the weight of deposited matter in major industrial districts and in those cities which were effected by the pollution to a considerable degree in 1958. Differences in the degree of pollution found between each part of the respective cities proved in general to be large, and showed that the principal source of pollution was industry.

Liaison organizations for expediting research and investigation are as follows:

Liaison Meeting for Air Pollution Research in Kinki Zone;
Liaison Council for Abatement of Air Pollution (consists of six cities in Fukuoka-Ken);
Technical Committee for methods of Air Pollution Abatement in Keihin Industrial Zone, Kanagawa-Prefecture.
Health Department of Communities Council in Hanshin Zone (including five cities);
Research Council of Air Pollution in Kobe Area;
Air Pollution Department of Workshop Management Council in Amagasaki.

Of the research reports made public since 1950, 46 articles were stated in the convention of academic societites and 50 articles appeared in some periodicals.

Those local bodies issuing reports of air pollution are Kanagawa-Ken, Kobe-Shi, and Sapporo-Shi.

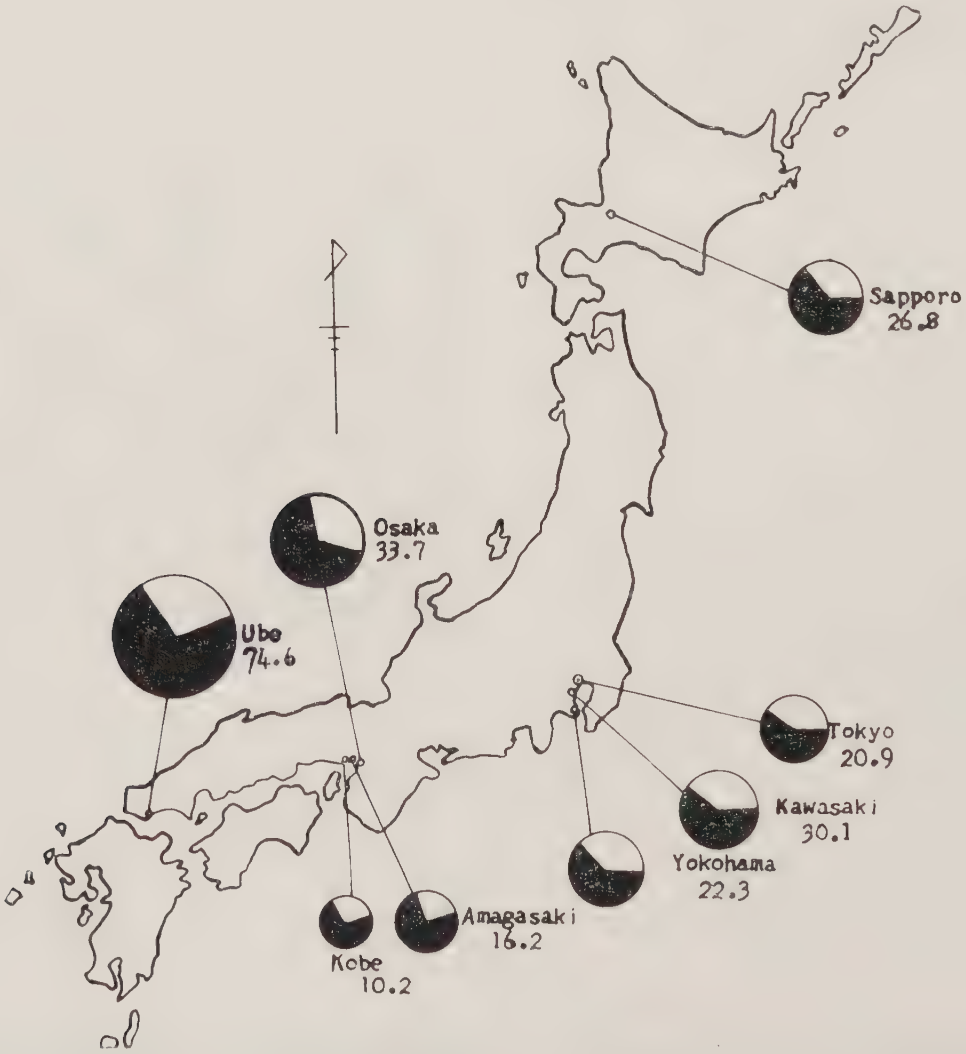


Fig. 2. Monthly mean weight of deposited matter in some cities in Japan (industrial areas) 1958, except Sapporo (1956).

THE DURBAN CLEANER AIR CAMPAIGN

K. R. JOHNSON, Air Pollution Control Engineer, City Engineer's Department, Durban, South Africa

SUMMARY: Durban is not only a major port and South Africa's main holiday resort, but is also a thriving industrial city. Coal is the principle fuel and its use by unskilled stokers gives rise to considerable smoke. This combined with frequent inversion conditions, produces smog. Smokeless zones are being created and a close check kept on all plans for new buildings to avoid potential nuisances. Smoke Control by-laws have been created to prohibit industrial smoke, and successful arrangements made for the training of stokers. All new plant must secure prior approval. A merit system for firms, based on standard smoke observations, has been instituted. Public Service vehicles may have their licences withdrawn if they emit excessive smoke. Railways, ships and special processes also come under the control of the municipality and are being dealt with.

Introduction

Durban is the principal East coast port of South Africa handling some 200 ships per month. It is also rightly known as the Union's main holiday and winter resort and has a mixed population of approximately half a million with all the industrial development necessary to meet their requirements plus other major industries which have been attracted to this port, including an oil refinery, whaling station and sugar refinery, etc.

The Problem

Bituminous coal is cheap at 50–67s. per ton and a large proportion of boilers are hand-fired by non-European stokers who, until recently, were untrained and had no idea of smoke control or the reasons for it. Despite the unskilled stoker force, steam generation by oil, liquid petroleum gas or electricity costs three to four times as much as coal unless for short-term or intermittent use, and coal therefore remains the main fuel used in Durban.

The climate of Durban is equitable and there is little necessity for space heating even during the winter months from June to August, but inversion conditions exist in winter and the area is surrounded by hills from 250–450 ft in height on three sides and the Indian Ocean on the other. Any smoke generated tends to form a heavy industrial haze or smog in the confines of the inversion layer as illustrated in the diagram, " Smog Formation ".

By correlating the meteorological data with figures for the hourly variation of smoke concentration and with visual observations throughout the city it has definitely been established that under present conditions if an inversion rate of more than 1°C per 100 ft exists, i.e. if the temperature increases at this rate instead of dropping as it should normally at the rate of 2°C per 1000 ft, then the present smoke emission will give rise to smog formation. The variation of smoke concentration, measured by drawing hourly air samples through a rotating filter paper, clearly indicates that sometimes the smog noticeable in the morning has its origins the previous late afternoon and evening when the instrument records a noticeable increase in smoke concentration. The onset of inversion conditions in the late afternoon has also been confirmed by temperature measurements using a captive balloon over Pretoria. Table II shows how these inversion and smog conditions in Durban increase during the winter months.

In the solution of this problem a number of novel approaches are being used which may be of interest to those concerned with smoke control generally, and these aspects are considered below.

Smoke Control

Complaints

While there is little recourse to space heating in the residential areas, coal is predominantly used by hotels and blocks of flats, which characterize the modern South African city, for hot water and cooking purposes. Due to the difference in elevation of adjacent buildings it is not uncommon for one old established hotel to smoke out a new 14-storied block of flats, to the annoyance of the tenants. Individual complaints are dealt with as they occur by advising of the simplest and cheapest method of overcoming the nuisance and

Table I
Coal Consumption in Durban

Consumer	*Coal used Tons per year*	*Percentage of Total*	*Fuel Burning Appliances Involved*
Power Station ...	500,000	43	Pulverized fuel boilers with Cyclones and electrostatic precipitators.
Industry ...	400,000	34	Ranges from small inefficient hand-fired boilers to large modern mechanically fired plant.
S.A. Railways ...	180,000	15	Hand-fired locomotives, boilers, mobile cranes, etc.
Domestic ...	60,000	5	Predominantly hot water and cooking stoves of hotels and flats.
Harbour Craft ...	30,000	3	Hand-fired tugs, dredgers, etc.
TOTAL	1,170,000	100	Too much coal burnt inefficiently producing excessive smoke emission.

Table II
Inversion Data for Durban

Month	*No. of Mornings Inversion Existed*	*Highest Inversion Rate for Month*
June	23	2·750
July	29	2·000
August	22	1·280
September	11	0·030
October 1958 to February 1959	Only 5 mild inversions were noted.	
March	5	0·800
April	13	0·900
May	24	1·800

pressing for their adoption. An all-out campaign is afoot to encourage the use of smokeless fuel or mechanical firing equipment, and this is being supported by the introduction of Smokeless Zones, the first of which embraces the entire beach front area, some 426 acres in extent, where 1,500 tons of fuel are burnt every month, in the majority of cases on inefficient appliances by untrained non-European stokers. By-laws are currently being drafted to require hotels and flats, etc., to convert to smokeless operation within three months, but one year's exemption can be obtained if they are required to install mechanically fired equipment, and if the appliances have to be replaced entirely they will be allowed two years. The corporation has established a loan scheme whereby those persons required to incur expenditure for the implementation of air pollution control measures can apply for a 75 per cent loan repayable at interest over a period of five years. Other residential areas of the city will gradually be established as smokeless zones, and a close check is kept on all new plans submitted where taller buildings are likely to build over existing fuel burning appliances to the annoyance of the tenants. By joint negotiation with all parties concerned it is very often possible to avoid any nuisance being created.

Industry

Smoke control by-laws were promulgated on August 21, 1958, their main provisions being to prohibit smoke of density greater than Ringelmann No. 2 for more than three minutes in any half-hour period, and in the first year this limit was relaxed to smoke of density Ringelmann No. 3 to enable those concerned to make the necessary modifications and have their stokers trained in smoke abatement. The other main provision was the requirement of all persons wishing to install new fuel burning appliances to seek the prior approval of the City Engineer's Department to ensure that adequate control measures were incorporated in all new installations. To enlist the support of all concerned the Cleaner Air Consultative Committee was formed shortly after the appointment of the author towards the end of 1956, under the able chairmanship of Councillor Frank E. Cheek, and included representatives of industry, hotels associations, laundries, railways, electricity supply commission, etc. Six air pollution control inspectors were subsequently appointed and seven non-European stoker demonstrators, the intention being to advise all concerned on the measures they should adopt to control excessive smoke emission and train up the non-European stokers throughout the city of Durban. With the co-operation of the Natal Technical College the author organized courses aimed at the twin subjects of fuel economy and smoke abatement, and also arranged courses for non-European managers and stokers, but the majority of non-European stokers were trained on their own installations under the direction of the air pollution control inspectors and non-European stoker demonstrators.

To encourage the co-operation of the firms concerned a system of standard smoke observations was adopted which enabled a monthly list to be circulated to the firms, showing an order of merit in any particular class of fuel consumption. For example, there are 50 firms using in the region of 30 to 50 tons of fuel per month, based on 40 observations made throughout the month. Some firms consistently record no observable smoke, whereas others record smoke emission varying in density. This is assessed as smoke points against them on the basis of an emission of smoke of density Ringelmann No. 1 counting as one point, Ringelmann No. 2 two points and Ringelmann No. 3 three points against them. These lists are then arranged in order of merit with the firms with zero points at the top, and at the same time the best previous record is shown against each firm. This not only fosters the co-operative spirit between the firms but is used as the basis for presentation of certificates to those firms having the best annual smoke record.

These records also clearly indicate to the management concerned whether the engineers and stokers are keeping their smoke emission down to the standard which should be obtained by their firm or has been obtained in the past. Needless to say, any variation calls for a visit by the air pollution control inspector, and smoke charts are also supplied to the firms on which they can log the monthly returns and check any undue variations. These records are also used by some firms as a basis for a bonus scheme for the stokers, but their main advantage is that firms required to install new plant or carry out modifications are immediately aware that if they consistently figure at the bottom of the list then they will be pressed to carry out any necessary modifications at an early date. Without such a scheme they would tend to adopt the " Why pick on me " attitude, which delays matters.

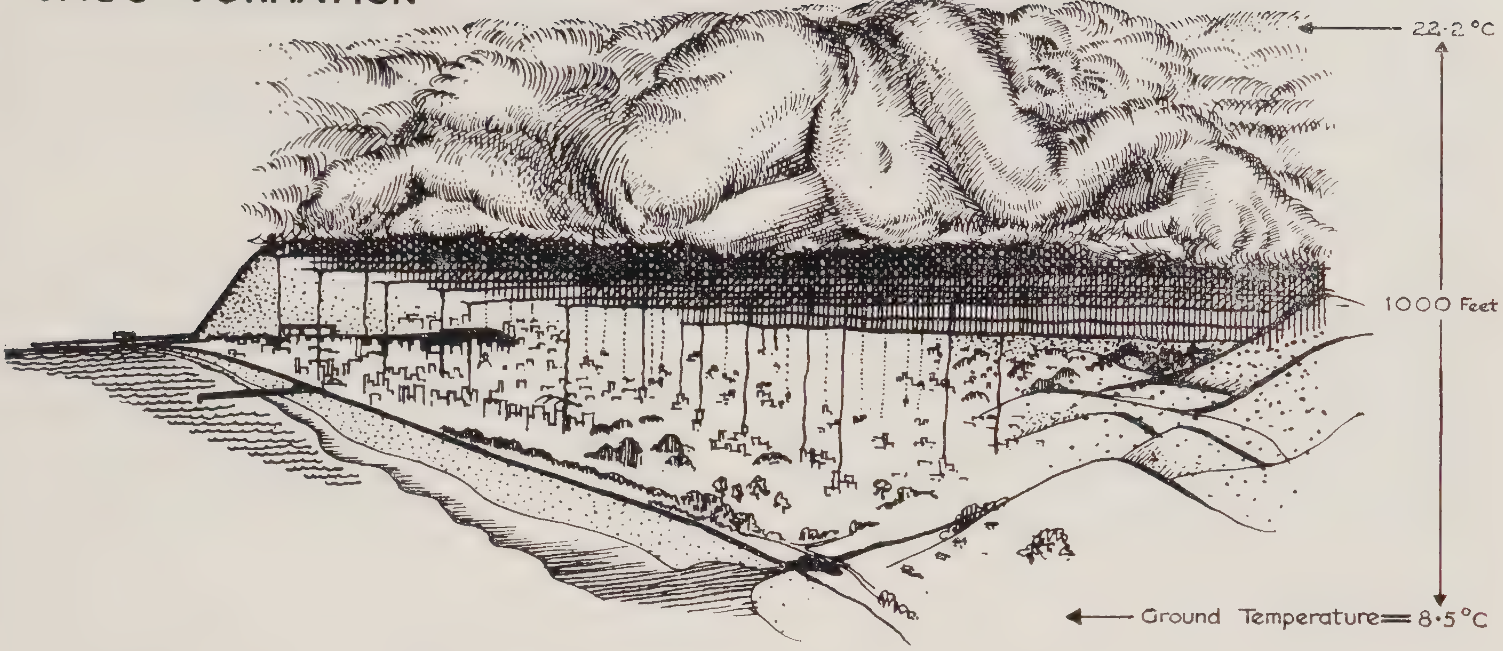
Since the inauguration of this system in 1957 the number of firms with no observable smoke emission recorded against them throughout the monthly standard observations has increased from 17 to 33 without the implementation of the by-laws, and this system has fostered that spirit of co-operation which is essential to the success of any campaign of this nature.

Railways

The locomotives in Durban are predominantly coal-fired, though electrification is gradually being intro-

IV. 48

SMOG FORMATION



INVERSION RATE $= \frac{22{\cdot}2 - 8{\cdot}5\ °C}{1000\ \text{feet}} \times 100 = 1{\cdot}37\ °C$ per 100 feet = SMOG

i.e. the temperature INCREASE of 1·37 °C per 100 feet stops Smog dispersal.

Under NORMAL CONDITIONS the Temperature is REDUCED by 2 °C per 100 feet and Smog disperses vertically.

duced. There are, however, some 500 footplatemen operating on coal-fired locomotives and, after representation by the corporation, the South African Railways administration arranged to appoint one of their retired system inspectors as a smoke control inspector, who now works in close co-operation with the corporation. A useful monitoring system has been evolved whereby the corporation's inspectors are authorized to draw the attention of all footplatemen concerned to any excessive smoke emission observed and to report the subsequent action to the system manager. In the vast majority of cases this system results in immediate remedial attention to the blower and over-fire air which quickly eliminates the smoke, and this is logged as a " good response ". In any month about 100 cases of excessive smoke emission from locomotives will be noted by the inspectors and on an average about 70 per cent will immediately rectify the emission; in about 10 per cent of the cases the response will be poor and in about 20 per cent of the cases, due to the operation of the locomotive, the inspector will be unable to attract the driver's attention. The railways' own inspector will then, from the number of the locomotive and the operational data supplied by the corporation's inspector, take up the matter with the footplatemen concerned.

At the same time the corporation has purchased a very excellent film, " Little and Often ", which illustrates the correct method of firing railway locomotives without excessive smoke emission and this is being screened at the main railway depots throughout the city of Durban to all trainee and other footplatemen.

Shipping

Attention is also given to incoming shipping in Durban as the harbour is adjacent to the main residential areas of the city. Representations are made to the majority of ships visiting Durban monthly to advise them of the corporation's campaign and to enlist their support. This is obtained by the careful manner of approach and smoke emission in the harbour area is kept within very reasonable limits.

Public Service Vehicles

A large number of 'buses are required in Durban particularly by the non-European section of the community, and where these buses are operated by non-European owners engine maintenance and fuel filtration is not always all it might be. Due to the heavy loads and the gradients encountered in Durban, black smoke from diesel exhaust is a matter of much concern. In the Provincial Road Traffic Act promulgated in 1957 provision exists for taking vehicles off the road until this excessive exhaust smoke is rectified, and to date some 600 vehicles have, after inspection at the municipal testing ground, had their licence withdrawn until the necessary maintenance and repairs have been effected. In this aspect of the campaign use has been made of a recently developed photo-electric exhaust smoke meter which has the advantage that it can be operated inside a moving vehicle and used as a standard in the assessment of smoke emission which otherwise might prove a " bone of contention " between the vehicle operator and the inspector.

Control of Special Processes

The Durban municipality is also concerned with the control of other forms of air pollution within the city boundary such as dust, fume and odour emission. No controlling legislation exists at the moment, but these problems are resolved by joint negotiation with the concern involved which invariably results in the adoption of suitable control measures. In this respect Durban has a distinct advantage over municipalities in the United Kingdom where control of such industries comes under the jurisdiction of the alkali, etc., works inspectors. At the moment no such organisation exists in South Africa, but legislation for control of atmospheric pollution on a national basis is being considered and a draft Act has been formulated based on the British Clean Air Act, the Alkali, etc., Works Inspectors' Regulations and experience gained in the Durban campaign. Within the terms of this draft Act the Minister may at the request of the local authority authorize any person employed by that local authority to carry out the duties of the Minister's contemplated chief officer or inspectors within the area, and it is anticipated that in this way the municipalities in South Africa who are prepared to tackle the smog problem energetically will maintain control of all processes in their area. At the same time the smaller municipalities will be encouraged by the promulgation of this Act to adopt effective control measures with the assistance of the national authority.

Conclusion

Other papers from South Africa cover such aspects as the standard measurement of air pollution, which approaches that of similar towns in the United Kingdom, particularly where those towns in U.K. have forged ahead with the establishment of smokeless and smoke control zones over extensive areas. In this respect the author would like to pay tribute to the work of the National Society for Clean Air which has been largely responsible for encouraging and co-ordinating the activities of all municipalities throughout the United Kingdom and whose publications and activities act as a strong source of encouragement to all overseas members pursuing the clean air cause.

Acknowledgements

The author wishes to thank the City Engineer of Durban for permission to present this paper, and Councillor Mr. Frank E. Cheek, the chairman of the Durban Cleaner Air Consultative Committee, who is attending the conference as the representative of the United Municipal Executive of South Africa.

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IV. 49

THE STANDARDIZATION OF METHODS OF SAMPLING AND ANALYSIS

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SUMMARY: The author describes the various sampling and analytical procedures in use, especially in North America and the United Kingdom. The criteria for sampling and analytical procedures are discussed. International standardization is needed and should be sponsored by some international body such as W.H.O. or O.E.E.C. Points which need particular attention are suggested.

Introduction

Interest in methods of sampling and analysis of air contaminants has grown steadily in North America within the last decade. This has been reflected in the activities of scientific and engineering societies, university and industrial research organizations, and certain government departments and agencies on the local, provincial or state and federal levels. In Canada there are a number of studies in progress in this field under the sponsorship of the Occupational Health Division of the Department of National Health and Welfare, the Air Pollution Control Branch of the Ontario Department of Health, the Ontario Research Foundation, the Canadian Standards Association and the Toronto University School of Hygiene. Symposia have been held by the Chemical Institute, the Canadian Public Health Association and the Engineering Institute of Canada.

In the United States the subject is developing rapidly as the result of efforts of committees and symposia sponsored by the American Chemical Society, the American Society for Testing Materials, the American Society of Mechanical Engineers, the American Industrial Hygiene and Public Health Associations and the Air Pollution Control Association. Since the passage of the Federal Air Pollution Research and Technical Assistance Act in 1955, the U.S. Public Health Service has expanded the studies of the National Sampling Network and the studies of a number of community air pollution projects with the co-operation of state and local agencies. Methods of sampling and analysis figure prominently in such studies. An important body of information has arisen out of the Los Angeles Air Pollution Problem with significant contributions from the work of the Los Angeles Air Pollution Control District, the Air Pollution Foundation, the Franklin Institute and other organizations. Last, but not least, may be mentioned such studies of methods undertaken by the U.S. Atomic Energy Commission, the National Bureau of Standards and the Bureau of Mines in the detection and measurement of aerosols and gases.

These activities have resulted in a considerable increase in the scientific and technical literature on air pollution, with important contributions to our knowledge of methods of sampling and analysis for solid, liquid, vapour and gaseous contaminants. Among the more important recent technical resources in this field are the Air Pollution Handbook[20], the Air Pollution Abatement Manual of the Manufacturing Chemists Association[19], the Proceedings of three National Air Pollution Symposia[22] held in Pasadena, California, in 1949, 1952 and 1955, the series of reports of the Air Pollution Foundation[2], the published methods of Atmospheric Sampling and Analysis of the A.S.T.M.[4] and the valuable contributions that appear in journals of the American Chemical Society, the Air Pollution Control Association and many other societies. The International Journal of Air Pollution (London) has appeared recently, and contains authoritative papers from many countries, including the United States and Canada.

In 1957, the World Health Organization of the United Nations organized an Expert Committee on Air Pollution which reviewed the status of the overall problem at Geneva in November of the same year. Professor Cambi of Milan presented an admirable report on sampling, analysis and instrumentation at this meeting.[7] At about the same time an international sub-committee for co-operative research on the standardization of methods for measuring air pollution was established under the European Productivity Agency of the Organization for European Economic Co-operation. Thus the necessity for standardization of methods in this field has been recognized not only on national but also on international levels.

Major Contaminants

There are three main sources of origin for waste materials that contaminate the atmosphere. The first source consists of products of combustion of fuels, and waste products generated in the industrial, commercial and other activities of man. To this can be added the quantities of particulate and gaseous products of natural origin such as material arising from the decay of vegetation, the natural dust that is rendered airborne by wind, spores and pollen, the materials contained in precipitation and the products of volcanic activity and forest fires. Thirdly, one must consider the class of contaminants resulting from the chemical or photochemical interaction of waste products that may occur subsequent to their release to the atmosphere. This third source of pollution is aptly demonstrated by the history of the Los Angeles problem[15] but photochemical oxidation products of hydrocarbons and other organic compounds may occur in other areas as well. If the first two sources of origin, mentioned above, are considered to be primary sources of contaminants, the third source is clearly a secondary one.

For purposes of sampling and measurement, air pollution may be classified as follows:

1. Particulate Matter.
    - (*a*) Solid and liquid particles of relatively coarse size, greater than about 20 microns in diameter.
    - (*b*) Aerosols or suspensions of finely divided particles ranging in size from about 20 down to less than 0·1 micron.
2. Gaseous or Vapour Products.
    - (*a*) True gases such as sulphur dioxide, nitrogen oxides, carbon monoxide and dioxide, ozone, etc.
    - (*b*) Hydrocarbons and other organic and inorganic compounds; in general, substances that have boiling points below about 200°C.

3. Radioactive Compounds.
   Radioactive isotopes of nuclear fission products, consisting of aerosols and gases, mainly from atomic and hydrogen bomb tests, but comprising also the decay products of natural radioactivity.

As examples of the above may be cited the following isotopes; strontium – 90 and – 89, caesium – 137, carbon – 14, radioactive iodine, radioactive krypton and radon.

Criteria for Sampling Procedures

Statistical considerations will define the requirements for adequately representative samples, and will define the limits of reliability for practical sampling schedules. The statistical approach, as well as other procedural criteria, are dealt with in ASTM D1357-57[4] and by Cadle, Magill *et al.*[5]

Aside from the criteria established by statistical reasoning, analytical requirements may impose conditions with respect to size and nature of samples. Where sampling and analytical procedures can be conducted separately, that is where the analytical technique is not an integral part of an instrument designed to yield continuous readings, the sampling methods must take into account the practical limitations of analytical methods. The amounts of contaminants present in large volumes of air are often so small that analytical techniques are taxed to the limits of detection. Where this consideration applies, a compromise must be arrived at between size of air sample and refinement or development of analytical method.

General criteria of sampling procedures are as follows:

(1) There should be, if possible, no change of condition of the collected material by aggregation or by reaction subsequent to collection. If changes are unavoidable their nature should be known.

(2) A choice must be made between continuous and intermittent sampling in the light of the kind of information required.

(3) The significance of short-term peak concentrations for some contaminants must be appraised, and the sampling programme must be planned accordingly. An example is afforded in the case of vegetation damage by brief fumigations with sulphur dioxide.

(4) The importance of isokinetic sampling conditions must be held constantly in mind when particulates are sampled. Practical compromises are usually necessary, but the magnitude of errors introduced by anisokinetic conditions can be estimated, and the reliability of measured values can be judged accordingly.

(5) Air sampling without concurrent measurement of relevant meteorological parameters can fail to yield the maximum information of practical significance. The more important meteorological factors are wind speed and direction and atmospheric stability. Others are temperature, humidity and precipitation.

(6) The possible effects on the values to be determined of local topographic features, or the street and building pattern in cities should be estimated, and sampling should be conducted accordingly.

Criteria for Analytical Procedures

When analytical techniques can be employed which are independent of the sampling procedure, the usual criteria for accurate analysis are applicable. However, most specific problems of atmospheric pollution are concerned with the accurate measurement of quantities present only in trace amounts in collected samples. Questions of specificity, interference by other impurities and contamination of samples are important when dealing with the micro quantities of contaminants contained in large volumes of air. While the techniques at some stages of the analytical procedures are often essentially micro methods, the analytical problem, on the whole, is concerned with large volumes of air and moderate or large volumes of absorbent. The analytical tools found useful, and often necessary, in air pollution work include the full range of modern analytical resources such as gravimetric, volumetric, conductimetric, spectrographic, spectrophotometric (visible, ultraviolet and infrared), X-ray diffraction, electron microscopic, mass spectrographic, polarographic, chromatographic and biological methods. Each of the methods available in a modern well-equipped laboratory carries its characteristic limitations with respect to reliability, sensitivity and convenience, and no comprehensive enumeration of criteria applies with equal weight to all methods.

To cite a truism, analytical methods should be chosen which are commensurate in accuracy, dependability, convenience and cost with the quality of the sample and the precision of the information sought.

Detailed discussions of analytical criteria are available in A.S.T.M. D1605-58T[4], in Section II by Cholak of *Air Pollution Handbook*[9], and in *Sampling, Analysis and Instrumentation in the Field of Air Pollution*[7] by Professor Cambi.

Discussion separately of criteria for sampling and analytical procedures is inapplicable to many of the more recently developed instruments for continuous measurement of contaminants. In these instruments the analytical method cannot logically be considered apart from the sampling procedure. The operation of various sensing elements sometimes fails to take into account the more exacting demands of analytical specificity. Values indicated or recorded are sometimes concentrations of groups or classes rather than concentrations of particular chemical substances. In such instances the criterion governing the employment of these instruments is their usefulness in measuring continuously a property of air related, for example, to a group of substances. A consideration which outweighs the lack of complete specificity is the usefulness of the derived data in correlations with the data from continuously operated meteorological instruments.

In general the use of continuous recorders in a survey will afford useful pollution indices which may be supplemented by more specific sampling and analytical techniques. The applicability of any particular instrument must be judged on its own merits, and the meaning of recorded values in terms of values determined by more definitive methods must be ascertained. The automatic feature of continuous sampling devices is obviously an important practical consideration and conserves manpower for more exacting tasks.

Suggested Items for Standardization

Sufficient progress in the field of atmospheric sampling and analysis has been made in the United Kingdom, France, West Germany and other European countries and in the United States and Canada to justify international agreement, through appropriate committees, on the standardization of the following items and procedures:

(*a*) Definition of Terms and Units
(*b*) Dustfall
(*c*) Smoke and Suspended Particulate Impurities
(*d*) Sulphur Dioxide
(*e*) Oxides of Nitrogen
(*f*) Ozone or "Oxidants"
(*g*) Hydrocarbons
(*h*) Carbon Dioxide and Carbon Monoxide

(*i*) Aldehydes
(*j*) Fluorides

In North America, the activities of Committee D-22 of the American Society for Testing Materials will undoubtedly set the pattern for acceptable procedures in this field. The methods adopted by the Department of Scientific and Industrial Research in the United Kingdom are well known and have proved extremely useful for the measurement of dustfall, smoke or suspended impurities, and sulphur dioxide[10]. For many areas it is probably sufficient to characterize the extent of pollution in terms of dustfall, suspended impurities and sulphur dioxide by methods identical or analogous to those adopted by the D.S.I.R. However, the increasing concentration of motor vehicles in densely populated areas may make it necessary to expand such surveys of pollution to include carbon monoxide, hydrocarbons and oxides of nitrogen. Nitric oxide and nitrogen dioxide or tetroxide represent appreciable impurities in the exhaust products of internal combustion engines, especially diesel engines. Nitrogen oxides are also formed during the combustion of fuels, principally in high temperature furnaces.

Although some of the ozone present in the lower atmosphere and at surface is of natural origin and represents the fraction that has diffused through the air from the ozonized layer in the ionosphere and stratosphere, ozone or "oxidants" may be formed photochemically from oxides of nitrogen and from a variety of free radical reactions, as described by Cadle and Magill[6]. The ozone which is liberated in reactions which depend upon the action of sunlight on relevant atmospheric impurities, readily attacks hydrocarbons to form the corresponding ozonides and peroxides. Such oxidants are believed to be responsible for the crop damage, eye irritation and accelerated cracking of rubber noted in the Los Angeles area. Vegetation damage due to ozone or oxidants has been reported in other areas of the United States and in the southern Ontario region of Canada. The standardization of methods of analysis for such contaminants has become, therefore, a matter of some considerable importance.

Volatile and particulate fluorides are of special concern in the production of aluminium and in the preparation of phosphate fertilizers wherever calcium fluoride forms an integral part of the phosphates that are reacted with sulphuric acid. In North America the release of such fluorides has resulted in extensive damage to certain fruit species, to gladiolus and other flowers, and to some agricultural crops and coniferous forest species. The accumulation of fluorides in forage crops has led to considerable damage to livestock feeding thereon through fluorosis of the teeth and bones. In a number of cases, fluoride damage to vegetation has resulted from operations involving foundries, brick plants and ferro-enamel works. A steel plant in Utah has been involved in a large scale fluoride problem from the unexpected release of fluorides from open hearth furnaces because of the relatively high fluoride content of the iron ore used.

Dustfall

The measurement of dustfall has been employed for many years to determine the distribution, seasonal cycles and yearly trends of pollution from dust and ash in urban areas. For nearly forty years such data have been gathered systematically in the United Kingdom by means of a standard deposit gauge in many of the principal cities and towns. In the decade between 1944 and 1954 the number of municipal, industrial and other bodies co-operating in the investigation of atmospheric pollution rose from 77 to 222[11]. Comparative data have been published from time to time by the D.S.I.R. This represents probably the most comprehensive collection of data on dustfall by a standardized method of any country in the world. The contents of the deposit gauge are analyzed for soluble and insoluble matter, tar, ash, combustible matter, calcium, chlorides, sulphates, pH of the filtrate, and other components that may be of interest Results may be expressed in tons per square mile per month or grams per 100 square metres per month.

In North America, unfortunately, methods of dustfall measurement have not been standardized. A variety of collectors of various shapes and sizes has been employed and this makes it difficult to compare data collected in one city with those of another. In 1955 a committee of the Air Pollution Control Association (Pittsburgh) published detailed recommendations on a standard method for a continuing dustfall survey[23]. The shape and size of the recommended collector were those of an open top cylinder with a diameter of 5 in. (±1 in.) and a height or depth of 2 to 3 diameters. Fisher[12] has made a comparative study of dustfall measurements at identical sites with a number of collectors or gauges of various shapes and sizes corresponding to the British Standard, the Toronto gauge, the collecting bowl of the Detroit type utilized in the International Joint Commission study of pollution in the Windsor-Detroit area, and a glass jar of the type recommended by the A.P.C.A. From these results, various factors were obtained which make it possible to compare the data from one type of gauge with those of another, within certain confidence limits. Variations in the amounts of dust retained by collecting gauges of different shapes and sizes are inevitable due to differences in the effects of wind and precipitation on the retentive power of the gauges. However, it is possible to establish a high degree of correlation between one type and another, as has been shown by Fisher and also by Lucas[18]. It is obvious, therefore, that standardization of dustfall measurements can be effected on an international basis either by adoption of the British Standard Gauge or by agreement on the utilization of established factors to correct measurements of one type to those of another.

Suspended Impurities

The measurement of smoke plumes by a visual comparison method based on the use of the Ringelmann chart has been standard practice for many years. This has proved an effective guide for the enforcement of regulations relating to smoke emissions from fuel-burning equipment. Certain optical instruments, such as the umbrascope, have also been employed to measure the density of smoke in terms of the Ringelmann numbers or their equivalent, but such instruments have had limited usefulness.

Quantitative evaluation of suspended matter in the air, including smoke, is usually effected by filtration methods. In the United Kingdom the standard instrument for this purpose is the automatic smoke filter developed originally by Dr. Owens[24]. A similar type of instrument has been employed in North America during the last five years as described by Hemeon *et al*[16]. The basis of these methods is the collection of suspended impurities by filtration of measured volumes of air through a filter paper or tape over a definite time cycle and evaluation of the circular spots of constant area by optical measurement of light transmission or reflectance. In the British method the results are converted to mass concentrations such as milligrams per 100 cubic metres of air by suitable calibration. The American method of expressing the results is to relate the optical absorbance of the deposit over a constant area of paper to the volume of air passed through the paper, or optical absorbance times 100 per 1,000 linear feet of air (Coh units per 1,000 ft. of air).

A review of filtration methods for evaluation of aerosol contaminants has been presented recently by Katz and Sanderson[17]. The basic instrument employed for the determination of particulate matter in the National Air Sampling Network of the U.S. Public Health Service[3] is the high volume sampler. This instrument is capable of filtering air at a volume flow of 30-50 cubic feet per minute through a highly efficient fibre glass filter. The collected material is weighed after a 24-hour or longer sampling period and may be analyzed spectrographically for various metal and other elements and for chlorides, sulphates, fluorides and nitrates. The results are expressed in terms of micrograms per cubic metre, or multiples thereof, of air.

Agreement on international standardization of the method of evaluating smoke or suspended impurities should not involve any great difficulty in view of the experience over many years with the British automatic smoke filter or the more recent experience with the Hemeon smoke sampler in America. A comparative study of both instruments under similar environmental conditions should provide the basis for an appropriate conversion factor. The utility of the high volume air sampler has been proven in the studies of the U.S. Public Health Service and in the Windsor-Detroit Air Pollution Study. It is understood that this method of collection of particulate matter is under examination by the Working Party of the Committee for Applied Research of the O.E.E.C.

Sulphur Dioxide

As in the case of dustfall and suspended matter, the extensive experience of the D.S.I.R. and co-operating bodies in the United Kingdom with the lead peroxide apparatus and the volumetric method for the determination of sulphur dioxide has provided a valuable collection of data extending over many years. In the lead peroxide method a small cylinder or "candle" coated with lead peroxide is exposed to the air for one month and subsequently analyzed for sulphates. The results are expressed in the empirical units of mg. of sulphur trioxide per day per square decimetre of standard peroxide area exposed. The instrument is protected from rain during exposure by enclosing the candle in a louvred box such as a Stevenson screen. This method of determination yields an average value for sulphur dioxide exposure which may be related to the volumetric determination of sulphur dioxide in which a measured volume of air is passed through a solution of hydrogen peroxide over a 24-hour period and the amount of acid collected is determined by titration with alkali. The appropriate conversion factor is given in reports of the D.S.I.R [10], [11]. The British lead peroxide method is finding increasing use in North America. In a recent study by Foran, Gibbons and Wellington[13] the results obtained by the lead peroxide method were compared with continuous sulphur dioxide measurements made with a Thomas autometer in which the resultant acidity was determined by electrical conductivity. A conversion factor was derived to relate the two methods and the correlation coefficient was as high as $+0{\cdot}94$. It is apparent therefore that the lead peroxide method, the volumetric method, and the Thomas autometer continuous instrumentation technique can all be related by appropriate conversion factors. International agreement on these procedures would therefore serve a very useful purpose.

Other Contaminants

Sufficient information is available in the scientific literature to serve as the basis for acceptance of one or more methods for carbon dioxide, carbon monoxide, and possibly nitrogen dioxide The A.S.T.M. Committee D-22 have recommended recently a tentative standard for nitrogen dioxide in air, D1607-58T. No completely satisfactory method having the required sensitivity has been evolved, as yet, for total oxides of nitrogen, although this problem may be solved in the near future. With respect to ozone or oxidants, several chemical methods have been employed by various investigators. These are based mainly on the liberation of iodine from potassium iodide in neutral, buffered, or alkaline solutions. Haagen-Smit has described a method of atmospheric oxidant analysis in which a phenolphthalin reagent is employed[14]. The methods are empirical and subject to interference from other contaminants such as oxides of nitrogen and sulphur dioxide. Some investigators prefer to rely on the rubber cracking test, suitably calibrated, as an index of ozone or oxidants. The consensus is that no practical method of the desired accuracy has been developed as yet for the measurement of ozone or oxidants in polluted atmospheres. In the Los Angeles area the Air Pollution Control District employ potassium iodide, phenolphthalin and rubber cracking in simultaneous tests.

With respect to fluorides, a test for inorganic fluoride, based on the method of Willard and Winter[26], with the incorporation of later modifications, has been proposed in A.S.T.M. D1606-58T. Several instruments have recently been developed for the continuous determination of fluorides. One of these is the Mini-Adak developed by Adams, Dana and Koppe[1] of Washington State College, Pullman, Washington. This instrument employs a Zirconium-Eriochrome Cyanine R reagent and the change in colour produced by absorption of fluoride is measured by light absorbance at 550 millimicrons. Another instrument developed at the Stanford Research Institute employs the principle of the selective quenching of the fluorescence of magnesium oxinate by gaseous fluorides[8]. The accuracy of such instruments for the determination of total fluoride in air has not, as yet, been established.

Discussion

The standardization of methods of sampling and analysis of contaminated air on an international basis is a problem that requires sponsorship by some international organization such as the World Health Organization or the Organization for European Economic Co-operation. In the case of the latter agency a good start in this direction has been made with the organization of an active Working Party. Recent developments in W.H.O. indicate an increasing interest in the various aspects of the air pollution problem. It is suggested that the following points of interest require co-ordinated attention and clarification:

1. *Planning of air pollution surveys*

   Much time and effort have been expended in the past on air pollution studies that show a lack of co-ordinated planning and a lack of appreciation of the statistical character of the problem. Since the ambient air of a region is subject to the vagaries of weather, and is influenced by the climate and topography of the area, the concentration levels and frequency of occurrence of atmospheric impurities vary accordingly. The collection of samples must be governed therefore by clearly defined objectives with respect to the character of the information required, as for example, the types and properties of impurities released from offending sources, the average concentration levels as contrasted with short period peak concentrations, the diurnal variation of pollution, the seasonal variation and long term secular trends. It is clear therefore that the planning of such studies involves a properly defined statistical approach in which due consideration should be given to the collection of meteorological as well as pollution data. Apart from statistical considerations, the duration and scope of the study are influenced by other factors which must take into account the objectives of the investigation, such as whether the information required is to determine the effects of pollution on health, extent of damage to vegetation, economic aspects, corrosion of materials, or the nature of control and remedial measures.

2. *Selection of sampling sites*

In the selection of sampling sites, some classification of the area under study should be made with respect to the types of activities prevailing in definite zones. Such zones may be classified, for example, as industrial with various pollution potentials, commercial, residential of high or low density, suburban and rural. Sampling sites must have a relatively unobstructed exposure, free from purely local influence such as the proximity of buildings or chimneys. It is important to fix reference heights at which equipment may be set up to sample for deposited matter, suspended matter, sulphur dioxide and various other gases. The number of sampling sites for a given region should be determined by statistical considerations based on the nature of activities within each zone.

3. *Instruments and sampling methods*

The choice of instruments and sampling methods will depend upon the objectives of the study, financial resources and available staff. There is no doubt that the basic instruments and sampling methods as employed in the United Kingdom for deposited and suspended matter and for sulphur dioxide represent the best approach for urban studies where financial resources and staff are limited. If the required funds are available, a study of this type can be readily expanded to include continouous instrumentation for short period average and peak concentrations, the diurnal variations, and conditions during the onset and breakup of inversions. The usual meteorological instrumentation installed at one or more key sites should accompany a basic study of this kind. Here also, a more elaborate study would involve a meteorological tower installation for the direct determination of turbulence and vertical temperature gradients.

4. *Analytical procedures*

The choice of analytical procedures depends upon the types of impurities prevailing in the study area and whether the sources of emission are intermittent or continuous. In North America considerable emphasis has been placed on continuous instrumental analysis for aerosols, sulphur dioxide, nitrogen dioxide and oxidants. However, these methods are not completely specific and are only indicative of groups of contaminants that produce the response of the sensing elements based on conductimetric, photoelectric or other principles. Specific methods are highly desirable but are confined, as yet, mainly to chemical analytical procedures that have not been reduced to automatic instrumentation. The mere availability of an instrument should not form the basis for its use. Other requirements must first be met, such as the degree of precision, the accuracy of the sampling device and that of the analytical method contributing to the overall accuracy of the results. The reproducibility of a given method or instrument is an important criterion aside from its efficiency of collection because a procedure of limited collection efficiency may still be useful if the results are reproducable.

5. *Treatment and correlation of data*

The importance of adequate statistical treatment and correlation of data on pollution levels with meteorological and other factors is demonstrated clearly in the D.S.I.R. Report on Atmospheric Pollution in Leicester[10]. A graphic multiple regression technique has been employed in the correlation of pollution with weather factors in the Detroit-Windsor air pollution study and the development of a weather index of pollution[25]. Munn and Katz[21] have discussed recently the daily and seasonal pollution cycles in the Detroit-Windsor area as derived from an extensive statistical tabulation of data on suspended matter, sulphur dioxide, and related meteorological observations from instruments on a high television tower. The results were coded on punch cards and subjected to electronic computer analysis.

These are examples of a developing trend in the handling of air pollution data and indicate the desirability of a standardized approach to the collection, reporting and correlation of results on a statistical basis.

Acknowledgment

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IV. 50

THE NEED FOR STANDARDIZED METHODS IN AIR POLLUTION SURVEYS

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SUMMARY: The author points out that the lack of standardization in methods and apparatus makes it difficult if not impossible to make international comparisons of air pollution measurement. A committee of experts is suggested, who should as expeditiously as possible, work out simple but exact procedures and apparatus.

All workers in this sphere know that, on the one hand, for distinct experiments standard procedures are not available. On the other hand there are so many and largely similar methods that many workers are calling for them to be made uniform and standardized. Consequently, to call for standardization is not new, yet it seems urgent to constantly repeat it. Already in the Summary Report of the conference on Public Health and Air Pollution in Europe, Milan, November 1957, it was said (page 11):

> ". . . It appears that differences result from measurements taken at the same time at the same place by different types. This difficulty may be overcome in the future by the use of standardized continuous recording apparatus. . . ."
>
> ". . . A great difference in measuring apparatus and of techniques was revealed pointing clearly to a need for standardization at international level. . ."

Though the above-mentioned conference was held two years ago these requirements have hardly been justified.

May I refer to two actual cases?

I intended to use the aspiration method for a precise research purpose as it is differently quoted among other things in the Milan conference report.

A comparison shows the following practice:

Page	*Author*	*Sampling Time*	*Aspirated air per hour*
147	Bergshoeff and Brasser	4 hours	750 litres
147	Bergshoeff and Brasser	continuously	120 litres
219	Paccagnella and Dechigi	24 hours	2,100 up to 5,210 litres
220	Paccagnella and Dechigi	—	300 up to 900 litres
279	Zhdanow	10–20 minutes	9,000 up to 10,800 litres

Naturally the purpose (determination of dust or gases), and above all the apparatus, are not the same, however similar. But is it possible to compare the results?

For determinations according to the *sedimentation method* the following "rain gauge" types are available, e.g. in Great Britain and the Netherlands:

		Receiver	*Diameter of the same*
(1)	British Standard Deposit Gauge	bowl-shaped glass	$12\frac{1}{2}$ in. =318 mm
(2)	The reduced constructional form of it	polystyrene funnel	8 in. =203 mm
e.g. in Germany:			
(3)	Type Liesegang-Lobner	bowl-shaped glass	305 mm
(4)	Type Bergerhoff	preserving jar	89 mm
(5)	Type Mirisch-Ost	polystyrene funnel	250 mm

Probably this column can be enlarged if desired by types used in other countries. Therefore it is evident that the results which are obtained by such varying receivers are not comparable, especially as the exposure times (7 days, 4 weeks) also vary. If only the diameters of the respective receivers were different it would be possible to make comparisons. But the shape of the receiver is much more decisive, and therefore this above all should be standardized.

At this place it is useless and misplaced to enter into particulars and to discuss the removal of anomalies. *I only want to beg for sincere co-operation on an international basis, on account of my own experience, with respect to the necessity of standardization, and to propose that a number of experienced specialists of different nations should meet here in London with the intention to help to solve this problem.* Higher than their scientific experience must be set their will to come to an agreement and to find quickly those procedures the general application of which can serve as a basis for research in air pollution and which may help it decisively.

With respect to the standardization of essential procedure it will be desirable to distinguish between:

(*a*) simple procedures with cheap apparatus for widespread investigations which according to their purpose can be set up in great numbers and which will render possible continuous measurements; and

(*b*) scientifically exact procedures for more complicated apparatus for special cases and above all for testing and controlling the work named above under (*a*).

This committee of experts should apply itself to the standardization of procedures in use and to the development of new methods. In general the systematic development of the means of research should lie in its hands, and naturally detailed problems must be investigated by groups of its members. Not till we possess comparable, research findings, based on international standards, shall we be able to exchange and to analyse them. Only on such a commonly created basis will it be practicable to render possible the urgently necessary agreement on terminology and the creation of an international glossary of air pollution, together with agreements which will help the common tasks of research and the creation of a wider understanding in the fight against air pollution.

DUST MEASUREMENTS TO DETERMINE THE SOURCES OF EMISSIONS DAMAGING CROPS

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SUMMARY: A survey of dust fall in a market gardening area was made, to determine which factory was the source of damage to crops. The methods and results are described. The experience gained suggests that a large number of measuring points are needed, that the dust receivers should be simple, and raises the question of how long they should be exposed. It is also suggested that further analysis of the results and more truly comparable methods of measurement are needed.

It is not always easy to discover the reason and the extent of damage caused by pollution from an industrial plant to neighbouring agricultural land. It is even more difficult when not only one plant but a number of industrial works—especially in the densely populated Ruhr-district—are causing the damage. In such a case our Institute was instructed by the authorized Court to determine:

(a) whether on the garden estates in the neighbourhood of plant A, which are used by the plaintiffs, damaging immissions as dust and smoke did occur, and

(b) to what extent this damage was originated by plant A, or was caused by neighbouring plants.

The gardens concerned lie according to the attached sketch directly north-east of the plant A and consequently on the leeside of the prevailing south-west wind. It was no wonder that the garden owners complained against plant A. Yet the accused company referred to the surrounding works B–L, which at least in their totality must cause damage too.

With respect to the production of the plants concerned the question is chiefly—according to the attached map—one of coal mines partly connected with power stations and coke works, and also iron and steel works. Therefore not only dusts of different origin but also gases as SO_2 and NO_2 are the possible components of the air pollution, so that suspicion that the accused plant A might not be the solo culprit, must not be rejected.

In fact the order given to us forced us to choose different ways and to use a number of research methods, but because of the limited space here only the accomplished dust measurements can be reported and an analysis given of the results. The statement about height and distribution of the air-dust immissions was done according to the sedimentation principle. For some years our institute has used the method of Bergerhoff who uses as simple receivers mass-produced jars of 89 mm (= 3·5 in.) diameter. These have the advantage of being cheap and can therefore be set up in a greater number. Also in this case control points were not only distributed in the affected garden estates but also round the works as can be seen from the attached map which shows 68 measuring points in a relatively small area. Every week the receivers were exchanged and their contents with respect to the weight was picked up as waste steam residue. Over 48 weeks (21.4.1958–23.3.1959) we obtained more than 3,000 itemized results, which however are calculated as average air-dust precipitation for every measuring point in mg/m² per day.

Thereby we worked so that we at first obtained averages:

(1) for the measurements 1–28 (21.4.58–3.11.58)

(2) for the measurements 29–48 (3.11.58–23.3.59)

and we experienced a surprising approximation between the summer and winter months. The average of all measuring points came during the summer period to 961 mg/m² per day, and during the winter period to 973 mg/m² per day, so that we cannot confirm the increase of deposit during the winter season that is generally observed. From this the influence of the house coal cannot be ascertained; the reason is perhaps the already very high industrial main load.

By the summary of all 48 measurements we were able to obtain the averages for the year 1958/59 which are specified in the attached table and represented on the map. By consideration of the evident graduation of deposits according to the " legend " of this analysis, and having regard to the ascertained year winds from south-east we get rather important statements.

As up to date the experts have no uniform conception about the upper limit of the admissible dust sedimentation the measuring points 49, 51, 61 and above all 48 show with their values of about 500 mg/m² per day and less the lower limit of air pollution which can be locally found and reached in the immediate neighbourhood of the industrial agglomeration in the Ruhr-district. As now most of the measuring points show values under 1,000 mg/m² per day it must astonish much more that the points 4, 5, 6 and 7 which are to be reported and which lie in or directly adjacent to the terrain of gardens, reach dust sediments up to 1,687 mg/m² per day.

These dust immissions which greatly exceed the normal limit emanated evidently from the plant A as it lies on the leeside of the chief wind direction. Add to this that the average year values of the points on the leeside 1, 2, 3, 4, 5, 6, 7, 8, 9, and 17 yield an average value of $x_1 = 1{,}179 \pm 81$, whereas the corresponding average values of the points on the weather-side 53, 54, 56, 57, 58 and 59 yield an average value of $x_2 = 763 \pm 34$. The difference between the lee-side and weather-side values comes to 415 mg/m² per day (with the limit difference (1%) = 11·06 high significant) and represents the surplus load emanated by the plant A.

This seems the more clear as this load dies away to the north and is evidently limited by the line of the measuring points 10, 11, 14, 15, 16, 22, 21.

With respect to the recorded investigation the following thoughts may be of general interest:

(1) For dust measurements a great number of measuring points are needed. In the case in question 100 measuring points are not too many for a district of 4 × 5 = 20sqkm.

(2) Therefore the dust receivers must be simply made and cheap.

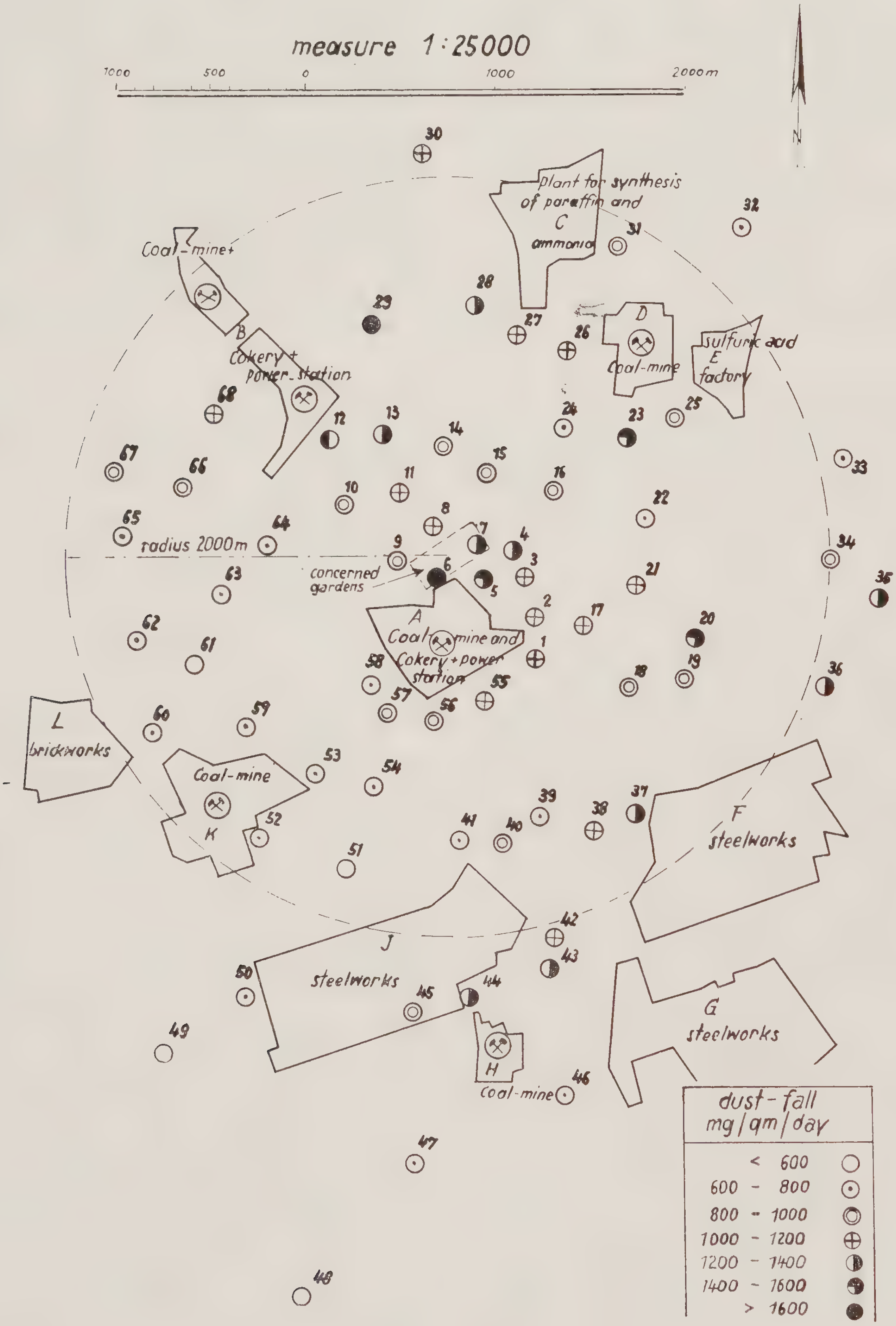
(3) The question arises, if the receivers must be exchanged every 7 days or if the exposure time can last 4 weeks.

The contention that better account is taken of meteorologic conditions by a weekly exchange carries little weight, as the wind continually changes its direction.

(4) With respect to the winning of the collection patterns which are loaded with no little costs the analysis of the "waste steam residue" as made by us does not satisfy.

(5) On the contrary every pattern makes necessary further analytic work where in particular the released gases and the pH-value must be found out.

(6) The careful interpretation of the findings of these disciplined investigations still requires completion by the development of methods which, while distinguishing between different emissions, will be so based on general principles as to permit the comparison of results.



IV. 51

Dust-fall mg/sqm/day

21.4.58–23.3.59

Gauge No.	*mg/m²/day*	*Gauge No.*	*mg/m²/day*	*Gauge No.*	*mg/m²/day*	*Gauge No.*	*mg/m²/day*
1	1,079	18	857	35	1,245	52	727
2	1,010	19	925	36	1,209	53	789
3	1,109	20	1,544	37	1,236	54	680
4	1,336	21	1,124	38	1,060	55	1,119
5	1,463	22	669	39	799	56	863
6	1,687	23	1,470	40	900	57	812
7	1,238	24	799	41	770	58	645
8	1,033	25	987	42	1,051	59	791
9	802	26	1,178	43	1,223	60	657
10	972	27	1,028	44	1,247	61	522
11	1,155	28	1,239	45	932	62	715
12	1,235	29	1,752	46	626	63	616
13	1,239	30	1,118	47	675	64	778
14	993	31	891	48	345	65	787
15	984	32	757	49	487	66	817
16	815	33	790	50	733	67	819
17	1,031	34	928	51	574	68	1,120

THE CALCULATION OF SULPHUR DIOXIDE AND SMOKE CONCENTRATION FROM DOMESTIC SOURCES IN CITIES

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SUMMARY: The present report is a simpler version of a paper published by the same author which attempted to give a quantitative expression of the amount of pollution which occurred in cities due to domestic fires. The method used in the original paper to find the concentration produced in the city under given conditions was to use Sutton's formula to estimate the concentration produced by individual houses at different distances. The concentration at a particular place in the city was obtained by calculating the concentration produced by the nearby houses and adding progressively the concentrations produced by houses further and further away. It is concluded that a major part of the sulphur dioxide and smoke pollution in cities is due to the emission from domestic fires.

Introduction

For many years the concentration of sulphur dioxide in towns and cities has been measured by the standard sulphur dioxide candle. This indicates the mean concentration measured over a month. More recently concentrations have been measured over an hour or even over a few minutes.[1] The concentration of smoke has also been extensively measured by smoke filter. These measurements and the general experience of life in cities has convinced everybody that there is a pollution problem and this has been often associated with the term " industrial " pollution. However, it must be pointed out that industries do not exist without houses and it is of great interest to the community to find out how much of the pollution is, in fact, industrial and how much is domestic.

A great deal of theoretical work has been done with a view to estimating the concentrations of sulphur dioxide likely to be produced by large industrial sources. So far, very little effort has been directed to estimating the concentrations likely to be produced by the thousands of small domestic sources which exist in our cities. However, the present author published a paper[2] which attempted to give a quantitative impression of the amount of pollution which occurred in cities due to domestic fires. This paper is very lengthy and complicated and there will be many people interested in the subject of air pollution who may not have the time or the inclination to work through it. It is the purpose of the present report to produce in a simpler form the results which were obtained in this paper, so that whenever a measurement of pollution is made in a city it will be possible to have some idea whether it could fairly be attributed to domestic pollution or whether the main cause of the measured pollution must be sought elsewhere.

The Basis of the Calculation

The method used in the paper to find the concentration produced in a city under given conditions was to use Sutton's formula[3] to estimate the concentration produced by individual houses at different distances. The concentration at a particular place in the city is obtained by calculating the concentration produced by the nearby houses and adding progressively the concentrations produced by houses further and further away. The theoretical formula allowed of course for the fact that the remote houses made a smaller and smaller contribution as their distance away increased.

The concentration calculated depended on:

(1) the amount of sulphur dioxide or smoke being emitted per unit area of the city (this itself depends on the time of day and time of year);

(2) the size of the city;

(3) the position in the city at which the concentration was calculated;

(4) the wind speed;

(5) the amount of atmospheric stability or instability;

(6) the height at which the sulphur dioxide or smoke was emitted;

(7) a number of other less important variables.

It is impossible to give a result depending on so many variables in an easily understood manner. It is, therefore, essential to introduce a certain amount of simplification in order to convey the general sense of the calculation. For a more detailed analysis, reference must be made to the original paper.

Simplification of the Problem

A number of simplifications can be introduced, which will, of course, affect the accuracy of the results but do not impair their interest. It has been assumed that the domestic chimney has a height of 30 ft. In fact, the height of emission will be somewhat larger because the hot gases rise after they leave the chimney. However, this rise in the hot gases can be neglected at all wind speeds above 5 ft/sec. At higher speeds than 5 ft/sec the concentration of sulphur dioxide produced by domestic sources is inversely proportional to the wind speed so that if a result is given at one particular wind speed the result at twice the wind speed can be obtained by dividing by 2.

The results given below are for conditions of neutral stability of the atmosphere. In general, concentrations will be greater when the atmosphere is stable and less when it is unstable.

When the wind speed drops below 5 ft/sec, under normal conditions, concentrations do not increase very markedly. However, if these is an atmospheric inversion, as in the London disaster of 1952, calculations show that concentrations increase very greatly. This is considered in the original paper but is too complicated to be adequately treated here.

It is strictly necessary to know the amount of sulphur dioxide or smoke being emitted per unit area from the city. This will not usually be known. However, it may be possible to estimate either the coal consumption, the number of houses, or the number of people per unit area. The relationship between these things on a national scale is fairly accurately known, and if we assume that the relationship does not vary very much from case to case, if we know any one of them, an estimate of sulphur dioxide concentration can still be made.

The emission of sulphur dioxide will vary with time of day. The variation in the emission rate of smoke will be still more marked. However, it has been assumed that the emission is constant during 16 hrs in each day.

The calculated concentration of sulphur dioxide can be compared with the concentration measured at any particular time. However, the measurement most commonly made is the monthly average concentration as estimated by the standard sulphur candle. This gives its result in mg/100 cm^2/day, but this can be conveniently converted to parts per 100 million of sulphur dioxide by multiplying by 2·5. The concentration measured during any month will depend on the frequency with which stronger and lighter winds occurred during the month. Again, these frequencies are accurately known for long period averages and can conveniently be applied to a single month without undue inaccuracy in most cases. The sulphur candle results in the Table have been obtained by using the wind conditions for the London area.

The calculated concentration of smoke can be compared with the hourly, or daily measured value or the monthly mean. The calculated monthly means in the Table have used typical wind conditions for the London area.

The concentration obtained in a city will vary from a very small value on the windward side to a higher value on the leeward side, and outside the city will fall off rapidly. The maximum value will usually be found about half way between the centre of the city and the leeward edge of the city, and very roughly speaking the concentration will be fairly constant from the centre of the city to the leeward edge. It will, therefore, be convenient to give a representative value for the leeward half of the city, rather than to give numerous details for the concentration at different parts of the city.

If these simplifications are made, the following Tables give the concentrations of sulphur dioxide and smoke due to domestic fires which can be expected in towns and cities.

Calculated Pollution in Winter for Cities of Different Sizes

Basic Data

Emission of SO_2: $1{\cdot}7 \times 10^{-8}$ ft^3/ft^2 sec } Cold weather, winter, day time
Emission of Smoke: $3{\cdot}1 \times 10^{-9}$lb/ft^{2}sec }

Coal Consumption: { 3 tons/10,000 ft^2 (annual)
3·7 lb/hr per 10,000 ft^2—(Cold weather, winter daytime)

Population Density: 4 per 10,000 ft^2

Houses: 1 per 10,000 ft^2.

The six basic data are approximately equivalent.

If in any situation the only known basic datum is different, the results should be adjusted accordingly. e.g. If the population density is 8 per 10,000 ft^2 all the figures given should be doubled.

Conclusion

The concentration of sulphur dioxide and smoke in towns increases progressively as the size of the town increases up to a diameter of about two miles. For towns of larger diameter the rate of further increase is small.

The concentrations of smoke and the sulphur candle readings which have been calculated for cities are of the same general magnitude as those which have been measured in cities for many years. It must, therefore, be concluded that a major part of the sulphur dioxide and smoke pollution in cities is due to the emission from domestic fires.

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Representative Results—Sulphur Dioxide

Dia. of City (ft) … …	1,000	2,500	5,000	10,000	20,000	40,000	100,000
Conc. in pphm Wind 10 ft/sec … … Cold	1	4	8	13	16	21	28
Conc. in pphm Wind 10 ft/sec … … Mild	0·7	2·7	5·3	8·7	11	14	19
Av. for 24 hrs (pphm) Wind 10 ft/sec … … Mild	0·42	1·7	3·3	5·4	7	9	12
Sulphur Candle mg/100 cm^2/day … … Average weather	0·17	0·67	1·3	2·2	2·7	3·5	4·7

Representative Results—Smoke

Dia. of City (ft).	1,000	2,500	5,000	10,000	20,000	40,000	100,000
Conc. in mg/100 m^3 Wind 10 ft/sec ... ... Cold	2·9	11·6	23	38	46	61	81
Conc. in mg/100 m^3 Wind 10 ft/sec ... ... Mild	2	7·8	15	25	32	41	55
Av. for 24 hrs mg/100 m^3 Wind 10 ft/sec ... ... Mild	1·2	5	10	16	20	26	35
Typical monthly mean . . . mg/100 m^3	1	5	10	16	20	26	35

The author would like to thank Dr. J. S. Forrest, Director of the Central Electricity Research Laboratories for permision to publish this paper.

IV. 53

DUST ABATEMENT FROM INDUSTRIAL GASES BY MEANS OF A SIREN DEVELOPED BY THE AIR POLLUTION CONTROL COMMISSION OF THE POLISH ACADEMY OF SCIENCES AND OF THE CENTRAL INSTITUTE FOR LABOUR'S PROTECTION

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SUMARY: During 1952 and 1953 a series of tests was carried out at the Warsaw Central Institute for Labour's Protection using an experimental ultrasonic siren as a means of cleaning various gases and smokes. The choice of a siren was determined by a theoretical analysis of the wave intensity value necessary. It was found that a number of vapours, smokes and dusts were precipitated. A series of practical tests were made on pilot scale plant, and high collection efficiencies were obtained.

In 1952 and 1953 at the Warsaw Central Institute for Labour's Protection (CIPO) an experimental ultrasonic siren (Fig. 1) and a testing stand were provided and a series of tests were carried out with various kinds of smokes, vapours and dusts, such as tobacco smoke, straw smoke, zinc oxide smoke, ammoniac salt vapours, cork dusts, rice flour dusts, and others.

The choice of a siren as generator of audio and ultrasonic vibrations was the result of a theoretical analysis of the wave intensity value necessary for an afficient precipitation of aerosols. From the wave intensity value

$$I = \frac{\rho \cdot v}{2}(2\pi f x)^2, \qquad (1)$$

we find

$$x = \frac{2}{\pi \cdot f} \cdot \frac{I^2}{(\rho v)^2} \qquad (2)$$

where:

x —amplitude of vibrations
f —frequency
ρ —particle density
v —acoustic velocity of sound wave propagation
(ρv)—acoustical resistance

From the above equation it can be seen that in a medium of low acoustic impedance (which is a property of gases) a wide amplitude must be attained if a high intensity is to be produced. This can be done easily by means of a siren.

On the laboratory stage the acoustic parameters of the siren were measured and the spatial directivity characteristic was found, together with the total acoustic power as a function of frequency and of the air volume per time unit supplied to the rotor of the siren. The measurements were taken with a P.A.N. (Polish Academy of Sciences) ultra-acoustic microphone for the rotor air expenditure Q=130, 250, and 400 cubic metres per hour, at various frequencies from 2·8 up to 23·18 kHz. It was stated that the directivity of the generator improved as the frequency increased (Fig. 2). Then the total acoustic power P was found under these conditions, as well as the absolute and decibel values for field intensity on the axis at 4 metres distance from the generator. The course of these functions is similar in all the cases (diagram in Fig. 3). In open space tests the maximum acoustic power P=830W was attained. Intensity showed the same kind of dependence on frequency.

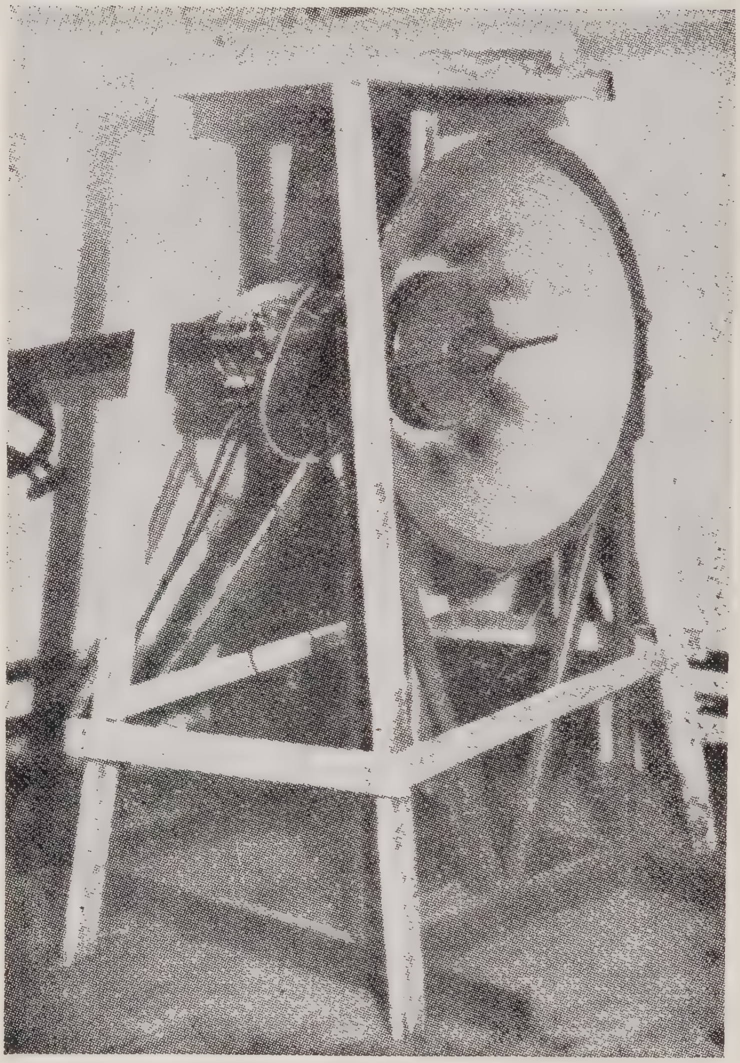

Fig. 1

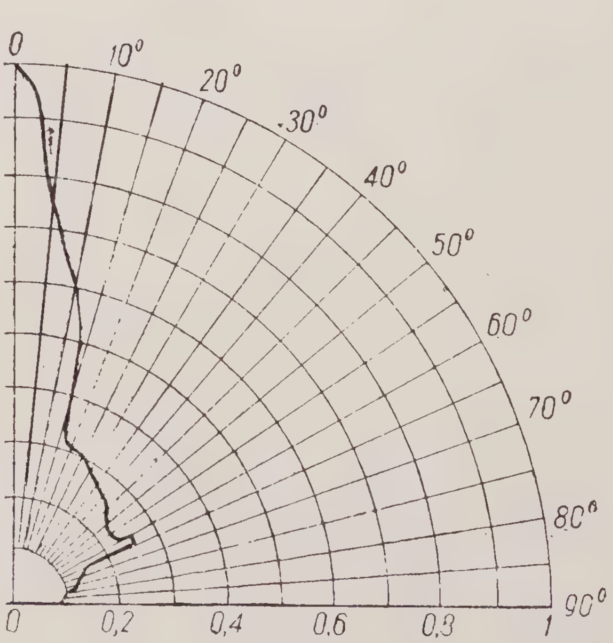

Fig. 2

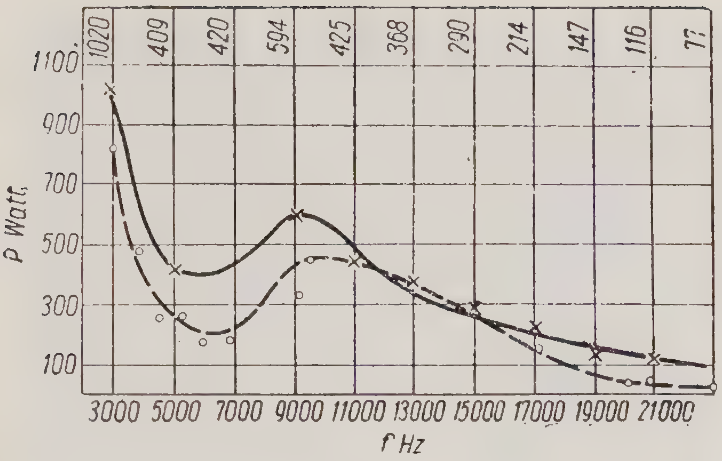

Fig. 3

Next to this the hydrodynamical characteristic of the siren was set up, defined by the changes in air output allowed to pass at various inlet pressures and at various numbers of revolutions corresponding to the frequency

$$f=0{\cdot}1 \cdot i \cdot \frac{\pi \cdot r}{30} n \text{ kHz} \qquad (3)$$

where:

n —number of revolutions per minute
i —number of openings in the rotor

The results of the measurements were represented by means of the diagram $Q=f(\Delta p \cdot n)$, showing the air output as a function of the pressure drop Δp and the number of revolutions n, and of the diagram $Q=f(P_G,n)$, showing the output against inlet pressure P_G and of the number of revolutions n. The coefficient $A=f(n)$ was found for the equation $P_G=A(n)Q^2$, from which the coefficient of discharge φ was determined

$$Q=\varphi\sqrt{\frac{2g \cdot P_G}{\gamma}} \text{ if } A=\frac{1}{\varphi^2 \cdot f_2} \cdot \frac{\gamma}{2g} \cdot$$

It was observed that the coefficient φ drops sensibly as the number of rotor revolutions increases.

For tests on the precipitability of aerosols a simple measuring jar was used first, after which an appliance was constructed for producing smokes and blowing them into a glass tube placed in the axis of the siren. A number of vapours, smokes and dusts were found able to be coagulated and precipitated by the acoustic method. Under the effect of audible or ultrasonic waves the aerosols gathered at the nodes and got deposited on the walls of the tube. On the ground of the tests performed in the Institute's laboratory a semi-technical experimental stage was mounted at the Szopienice zinc works (Fig. 4). Into a coagulation column of about 10 metres length, on which the siren had been placed, gases were supplied from a pit furnace for melting old copper. While passing through the column the gases become partly purified of aerosols, after which they get into the cyclone where further amounts of coagulated dusts are precipitated. The flow of the gases and air out of the rotor of the siren is a counter-current one. The measurements were effected at frequencies varying from 3 to 21 kHz. The tests lasted from under 20 minutes to 12 hours.

The results of the measurements of acoustic power and field intensities, when given the form of diagrams, revealed a dependence analogous to that observed in laboratory tests (see Fig. 2). The acoustic power would reach 1,020kW and amount to 1,204 if one considers that about 20 per cent of the energy escaped straight to the cyclone without passing through the measuring appliance.

Fig. 4

The abatement efficiency was 90 per cent on the average and in some cases even above 95 per cent (see Fig. 5). The acoustic measurements were taken by a group of specialists from the Institute of Basic Problems of Technology under the Polish Academy of Sciences. The tests proved that to dedust gases it is sufficient to obtain a field with an intensity of the order of 0·1 W/cm², which is in accordance with the results of Hungarian and Japanese research (Oyama, Inoue and others).

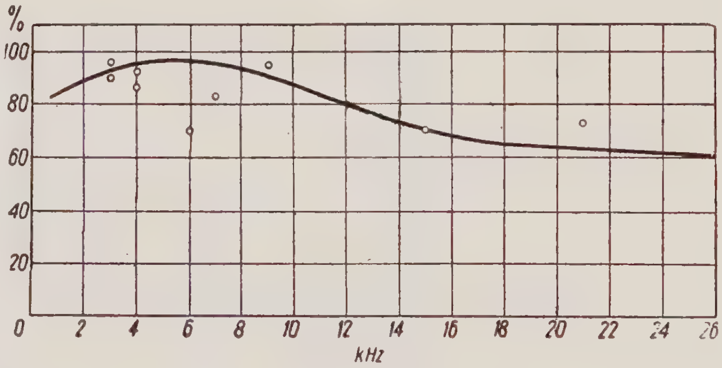

Fig. 5

On the ground of the experience gathered and the results obtained, further improved appliances have been devised. One of these is now being erected under the supervision of the Commission for Technical Air Cleaning of the Committee on the Upper Silesian Industrial Area (Polish Academy of Sciences). The plant under construction will allow a thorough study of the range of application of the acoustic method to dedusting industrial gases, a choice of coagulation and precipitation frequencies most suitable to each kind of dust or gas as well as an analysis of the profitableness of this method of dedusting.

By means of the above described appliance we could generate frequencies from 3 kHz upwards. In some cases these frequencies proved too high.

For the orthokinetic coagulation (Brandt and Hiedemann) of aerosols with the average particle size d=6 microns, the kind we had mostly to deal with, we started from the well-known ratio:

$$\frac{X_p}{X_G}=\frac{1}{\sqrt{1+\left(\frac{\pi\rho\cdot f\cdot d^2}{9\mu}\right)^2}} \qquad (4)$$

where:

X_p —the particle amplitude of the aerosol in microns

X_G —the particle amplitude of the gas in microns

f —the vibration frequency in Hz

d —the particle diameter in microns ($d=6$ microns)

ρ —the particle density of the aerosol in grams per cubic centimetre ($\rho=7$ grams per cubic centimetre)

μ —the air viscosity (0·245 poise at 100°C and 0·145 poise at 15°C)

and we calculate the necessary vibration frequencies of the acoustic wave generated:

$f_{\mu}=100^\circ C=2070$ Hz and $f_{\mu}=15^\circ C=1225$ Hz

In connection with the results of theoretical reasonings a supplementary apparatus was mounted to reduce the revolutions of the siren. Thus it became possible in 1958–59 to perform tests at 1·1 kHz, 1·5 kHz and 2 kHz frequencies (with small deviations).

In about fifty measurements the highest dedusting efficiency (93, 91 and 90·5 per cent) was attained at the frequencies f=1550 Hz and f=2050 Hz (Tables I and II).

The acoustic power corresponding to this frequency range was also determined and the diagram of radiated acoustic power as in Fig. 3 was supplemented so as to give the complete survey represented in Fig. 6. It can be seen that the maximum acoustic power measured was P=1127 watts and the actual acoustic power was $P_r=1412$ watts. The increase in acoustic power was about 17 per cent, and in acoustic efficiency—up to about 14 per cent.

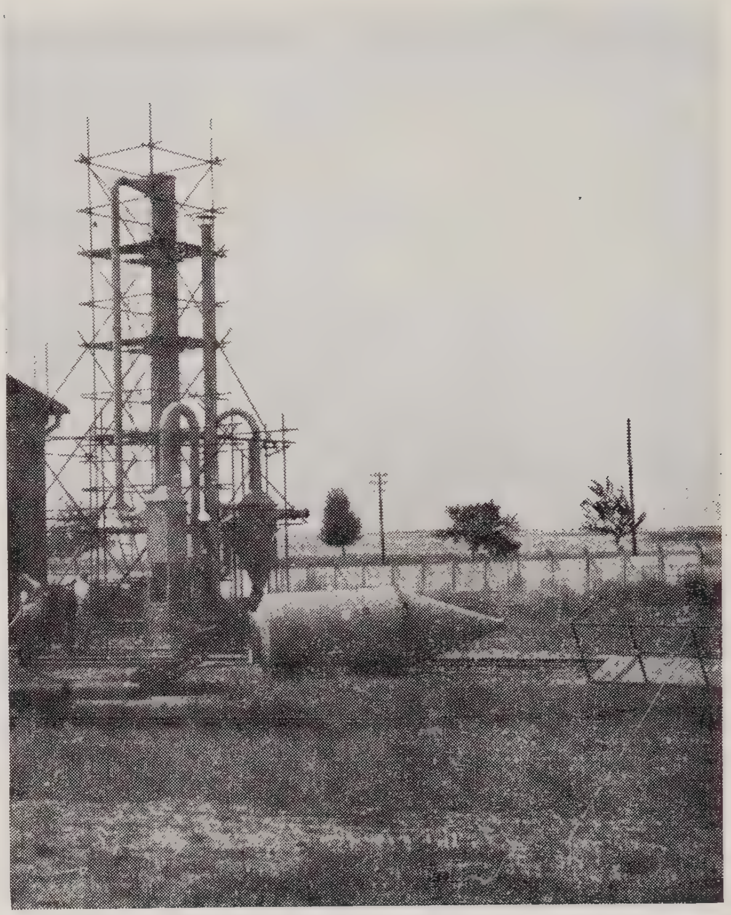

Fig. 7

The tests mostly lasted for about 2 hours and in two cases for 23 and 17·5 hours respectively. During all that time the siren worked without interruption.

Besides, a series of exact tests and several rough tests were effected on the dedusting efficiency of the appliance while the siren was out of work. From the measurements taken on 20th November, 1958, it followed that the dedusting efficiency with the siren at work was in the average 77·85 per cent, and with the siren out of work—39 per cent, i.e. by 38 per cent smaller; on other days, the latter was 23.09 by per cent smaller on the average.

The value for the dust content of the furnace gases was, as can be seen from the annexed tables, highly variable and oscillated from 1·7 g/Nm³ (on 19th

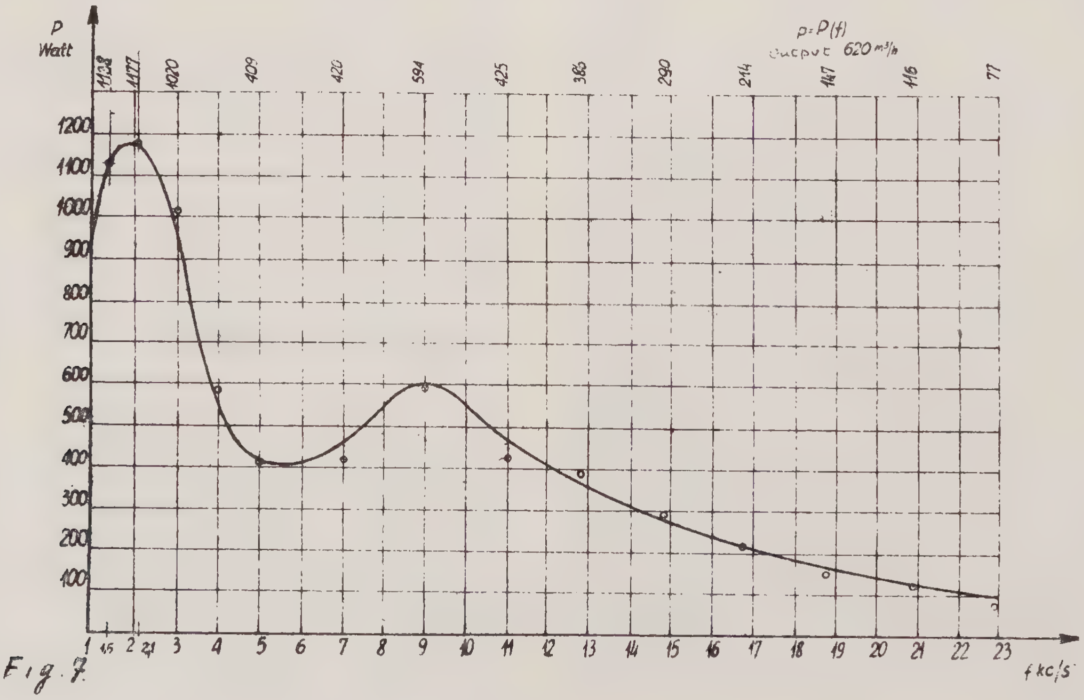

Fig. 6

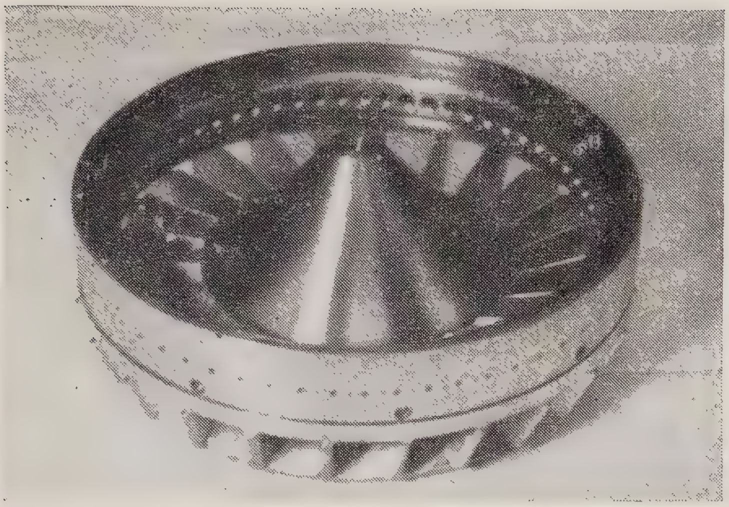

Fig. 8

November, 1958) to 17·73 g/Nm^3 (on 21st November, 1958).

Since it was decided, for economic reasons, that the copper melting furnace should be dismounted, we had to interrupt our tests.

We shall very soon finish mounting the above-mentioned new and not very large PAN-CIOP siren plant for in situ tests (Fig. 7) and then start a number of tests at a chemical factory on recovering certain rather valuable dusts now escaping into the atmosphere.

The plant is constructed so as to be easy to mount, to dismount, and to transport. It renders it easy to make the gases under purification circulate in either direction, counter-current or not. Besides, it allows them to be cooled and cleaned either at the inlet (by passing through a set of multi-cyclones (Fig. 7), or at the outlet only, or at both. The choice of the gas circulation system depends on the physical properties of the aerosols and on local technical conditions.

The construction of the siren, too, is such that the gas stream purified may be subject to the action of sound waves either in the well-known way, i.e. while flowing before the siren, or while flowing through the siren itself. For this purpose the PAN-CIOP siren has a bi-flow rotor to be seen in Fig. 8.

The frequencies we can generate range from 1 to 30 kHz. The amount of gases we shall be able to clean with this appliance will reach about 1,200 cubic metres per hour.

The results of the above second series of tests, with the CIOP siren will soon be published.

The tests on the new PAN-CIOP siren will be partly completed in 1960. We are planning some rather long-lasting experiments with this siren both as an independent dedusting unit and joined to other modern dust arresters, such as the CIOP Rotoclone and various types of cyclones.

These tests will show under what conditions and to what kinds of aerosols an acoustic dust arresting equipment, either audio or ultrasonic, can and should be applied.

The tests carried out at the Warsaw-Central Institute for the Protection of Labour have aroused a vivid interest abroad.

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Table I
Measurements of the Efficiency of the CIOP Siren

Date	*Quantity of Gas* NM^3/h	*Frequency* *f c/s*	*Dust Loading before Blast* g/Nm^3	*Dust Loading after Cyclone* g/Nm^3	*Efficiency per cent*	*Notes*
17 November 1958	—	1550	1·84	0·36	76	
18 November 1958	—	1550	0·36	0·12		
			3·30	0·95	65	
		average			70·5	
19 November 1958	2900	1550	2·75	0·20	93	
			6·14	1·61	74	
			1·70	0·84		
			4·53	0·83	82	
		average	3·78	0·87	83	
20 November 1958	1220	1550	2·83	1·73	39	No-sound test
			4·67	1·55	67	
			6·40	1·12	83	
			5·33	0·61	89	
			7·52	2·85	62	
		average	5·35	1·57	75	
21 November 1958	2640	1550	10·0	2·81	72	
			4·40	2·27		
			11·40	2·10	81	
			14·62	1·37	91	
			17·73	2·45	86	
		average	11·63	2·20	82·5	

Table II
Measurements of the Efficiency of the CIOP Siren

Date	*Measuring Point*	*Frequency c/s*	*Temperature t°*	*Pressure mm H_2O*	*Quantity of Gas Nm^3/sec*	*Dust Loading g/Nm^3*	*Quantity of Dust kg/h*	*Lineal Speed m/sec*	*Efficiency per cent*	*Notes*
12 Dec. 1958	before siren	2050	20–130	—20	0·573	11·6	24·0	6·06	90·5	
	after		30–38	+16	0·873	0·73	2·3			
19 Dec. 1958	before siren	1045	40–170	—15	0·725	7·22	18·85	8·0	73·6	
	after		43–51	+15	1·055	1·31	1·98			
20 Dec. 1958	before siren	1045	100–170	—16	0·324	6·97	8·15	4·02	44·7	
	after		32–36	+ 8	0·65	1·93	4·5			
22 Dec. 1958	before I	1045	80–140	—15	0·62	8·36	18·65	7·36	64·7	
	after		34–56	+11	0·88	2·08	6·58			
	siren before II	0	60–170	—16	0·64	4·38	10·0	7·15		Without siren
	after		56–72	+ 7	0·64	2·05	4·72			
23 Dec. 1958	before siren	1045	120–260	—14	0·48	12·1	21·0	6·73	46·6	
	after		85–96	+15	0·815	3·57	11·2			
24 Dec. 1958	before I	0	60–21	—14	0·536	6·66	12·8	6·8	31·7	Without siren
	after		85–96	+15	0·86	2·83	8·75			
	before II	0	100–210	—15	0·705	5·46	13·8	8·7	39·8	
	after		110	+13	0·705	3·19	8·3			
8 Jan. 1958	before	1500	170–260	—12	0·43	1·85	2·87	6·2	30·0	
	after		59–89	+10	0·76	0·74	2·02			
9 Jan. 1958	before	1500	130–265	—11	0·54	1·8	3·5	7·0	77·3	
	after		45–62	+ 9	0·87	0·156	0·8			

Table III
Results of Tests on CIOP Siren at Continuous Operation

Ordinal number	*Date*	*Starting and finishing time or duration of test hrs*	*Frequency f kc/s*	*Air pressure in network at m.*	*Pressure drop in flange mm. Hg*	*Rotor air output Nm^3/h*	*Gas output m^3/h*	*Quantity of dust precipitated kg*	*Notes*
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1	18 Oct. 1958 19 Oct. 1958	2.00 p.m. 23 1.15 p.m.	1·55	2	180	660	2900	137·5	
2	22 Dec. 1958 23 Dec. 1958	3.00 p.m. 17·5 8.30 a.m.	1·045	2·6	250	1160 580	3000	131	Where: under cyclone 90 kg under column 41 kg

Table IV
Results of Tests on Siren at intermittent operation

Ordinal number (1)	*Date* (2)	*Starting and finishing time of test* (3)	*Frequency f kc/s* (4)	*Air pressure in network at m.* (5)	*Pressure drop in flange mm. Hg* (6)	*Rotor air output Nm³/h* (7)	*Gas output m³/h* (8)	*Quantity of dust precipitated kg* (9)	*Notes* (10)
1	17 Nov. 1958	11.15 13.15	1·55	2·0	170	640	2500	27·2	Dust slightly damp
2	18 Nov. 1958	8.00 11.00	1·55	2·0	180	640	1200	2·1	Half-hour standstill
3	18 Nov. 1958	11.15 12.15	1·55	2·0	180	640	3100	10·1	
4	18 Nov. 1958 19 Nov. 1958	14.00 13.15	1·55	2·0	180	640	2900	137·5	23 hours work
5	12 Dec. 1958	10.45 13.15	2·05	2·5 2·8 2·4 3·0 3·0 3·0	220 250 250 190 250 250	1160		46·4	$\eta \simeq$ 93 per cent Measurement taken by Mr. Widera
6	19 Dec. 1958	11.00 13.00	1·045	2·4 2·0 2·5 2·4 2·6	230 200 235 230 260	1150	2600	10·0-c 15·0-k	c-before cyclone k-before coagulation column
7	19 Dec. 1958	13.30 15.30	1·045	—	—	—	2600	3·3-c 2·0-k	Siren switched off
8	20 Dec. 1958	9.45 11.45	1·045	2·6 2·6 2·6 2·4 2·8	260 255 260 220 270	1200	1200	6·4-c 6-k	Furnace damper shut dust pocket working
9	20 Dec. 1958	12.45 14.25	1·045				1200	1·6-c 3·6-k	Siren switched off. Furnace damper shut
10	22 Dec. 1958	9.00 10·25	1·045	2·8 2·2 2·2	250 200 210	1160	3000	7·5-c 9·0-k	
11	22 Dec. 1958		1·045	2·0 2·8	170 255			3·2-c 2·0-k	Siren switched off
12	22 Dec. 1958	12.20 14.20	1·045	2·4 3·0 3·0	220 295 300	—	3000	11·0-c 9·8-k	
13	23 Dec. 1958	9.48 11.50	1·045	3·0 2·65 2·8 2·7	285 265 280 255	1240	3000	13 -c 3·3-k	
14	23 Dec. 1958	12.10 14.10	1·045					3·3-c 4·8-k	Siren switched off
15	24 Dec. 1958	10.20 11.20	1·045	2·6 2·8 2·2	260 275 225	1200	3000	7·2-c 2·0-k	
16	24 Dec. 1958	11.40 12.45	1·045	2·8	275		3000	5·2	Siren switched off
17	29 Dec. 1958	9.00 11.00	1·045	2·4 2·6 2·7	220 250 255		3000	5·3-c 2·8-k	
18	30 Dec. 1958	10.00 11.20	1·045	2·0 1·8 1·7 1·0	180 160 150 105		3000	1·3-c 0·6-k	No air

Table IV continued

Ordinal number	*Date*	*Starting and finishing time of test*	*Frequency f kc/s*	*Air pressure in network at m.*	*Pressure drop in flange mm. Hg*	*Rotor air output Nm³/h*	*Gas output m³/h*	*Quantity of dust precipitated kg*	*Notes*
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
19	8 Jan. 1959	9.30 11.30	1·5	2·0 2·8 2·8 3·0 2·3	120 255 255 285 230	800	3000	1·8-c	Flange clack shut
20	9 Jan. 1959	9.30 11.30	1·5	2·1 2·7 2·8 2·9 3·0	180 245 260 270 270	1180	3000	2-c 1-k	

c—under cyclone k—under column

IV. 54

THE INVESTIGATION OF AIR POLLUTION IN PADUA DURING THE YEARS 1955–'58

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SUMMARY: The paper reviews the investigations carried out at Padua, using instruments and techniques based on British practice. The observations show that pollution is to some extent similar to that in many towns in Britain, but that there is a much wider ratio between winter and summer figures.

At the end of 1954, we initiated a systematic investigation of atmospheric pollution in the Padua area, following methods and with instruments suggested by the British Atmospheric Pollution Research Committee.

During previous times (1953–'55) we had carried out some investigations on atmospheric pollution, over the area Mestre-Marghera (Venezia), following a different method. Instantaneous samplings were taken and successive air specimen analysis were effectuated.

The results of our investigation were referred before the International Conference of WHO in Milan on Public Health Aspects of Air Pollution in Europe (6th–14th November, 1957).

A more simple and not expensive method was adopted for the control on the Padua area. This method, already widely used experimentally, is such as to enable us to make a comparison between our data and those recorded by other countries. For this reason we have followed the instructions given by the Fuel Research Station (HMSO, 1953) both for the construction of instruments and for the analysis procedure.

As for the deposit gauges we have used, from the beginning, some collecting bottles in polythene, which were found quite suitable, particularly in winter time because unbreakable. We are suggesting too the use of collecting funnels of the same plastic material, to avoid possible breakages caused by hail in summer time.

For sulphuric dioxide determination by means of ead peroxide cylinders, we have calibrated our amount of lead peroxide according to a specimen of the same reagent furnished by the Fuel Research Station of London.

We have installed in Padua 8 stations, located in different places over an extension area of 8,160 km. from north to south and 2,638 km. from east to west, with a population of about 198,000 inhabitants. The location of each station was carefully studied, according to the different sectors of the town (industrial zone, central and peripheric residential quarters, hospital quarters, etc.

Meteorological data were registered by the Meteorological Station of the town. In Fig. 1 and 2 mean values of atmospheric precipitations, temperatures and wind frequencies are reported in schematic diagram. Monthly mean values of deposited matter collected by means of deposit gauges in summer and winter time, are reported in Tables I and II. Values between parentheses correspond to standard deviations.

Values for sulphuric dioxide controlled by means of lead peroxide cylinders are reported in Table III, where mean values for the whole year and for summer and winter seasons are also represented separately.

From the above mentioned data it can be noted how these values are not much different from the ones determined in other town of England.

On the other hand, some differences can be found in the relation between simple fractions of deposited

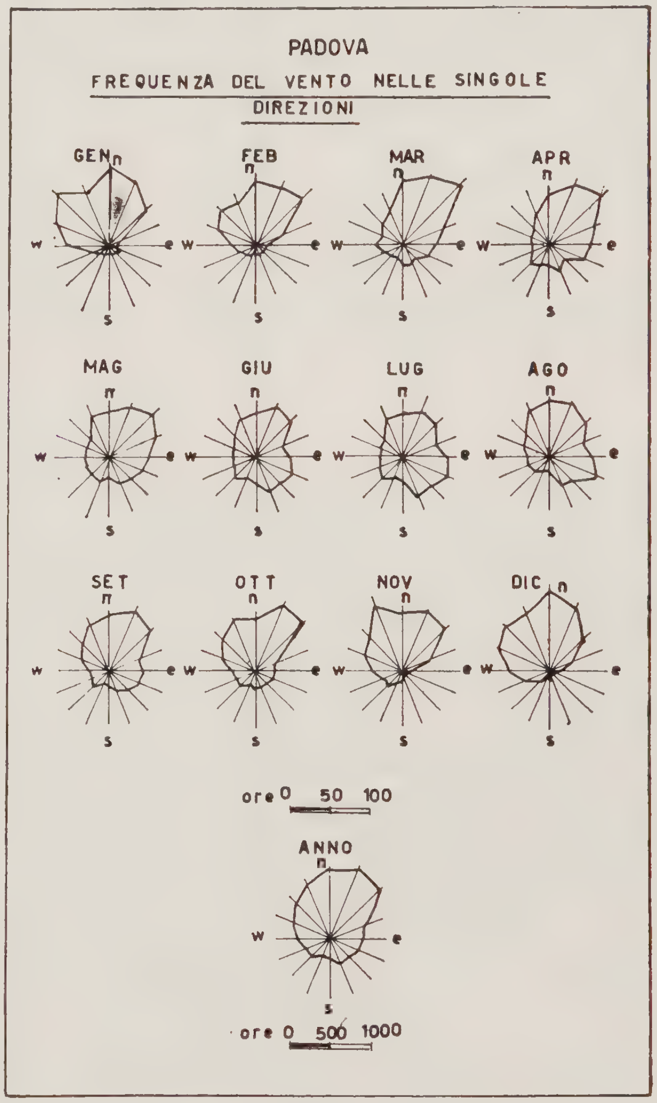

Fig. 1

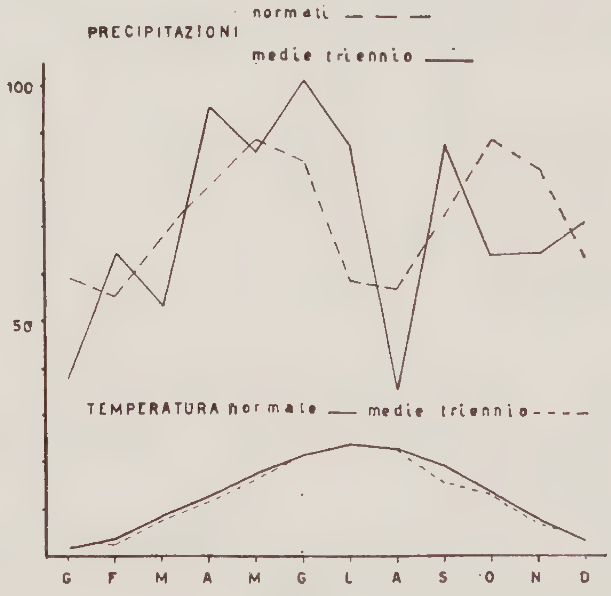

Fig. 2

Table I

Summer means of deposit matter. Means were calculated for the four years 1955–58 (Tons per sq. Km. per month)

	Station							
	1	2	3	4	5	6	7	8
Total undissolved matter	408 (188)	427 (94)	260 (82)	610 (208)	401 (106)	503 (90)	376 (69)	378 (82)
Tar (soluble in CS_2)	3 (3)	6 (5)	4 (6)	4 (4)	4 (5)	3 (4)	2 (2)	4 (7)
Insoluble ash	294 (167)	289 (82)	169 (59)	439 (140)	260 (71)	317 (78)	274 (65)	261 (61)
Combustible matter	111 (33)	132 (25)	87 (46)	167 (83)	130 (64)	182 (28)	99 (13)	105 (22)
Total soluble	343 (93)	468 (158)	332 (192)	603 (218)	412 (174)	292 (74)	337 (233)	383 (214)
Ca^{++}	63 (18)	86 (52)	63 (28)	167 (63)	100 (38)	89 (35)	65 (17)	62 (23)
Cl^{--}	18 (9)	40 (56)	15 (43)	17 (6)	11 (8)	11 (4)	18 (17)	14 (8)
SO_4^{--}	40 (33)	83 (34)	69 (23)	102 (25)	73 (41)	68 (29)	53 (13)	53 (23)
Total solids	751 (216)	896 (239)	592 (232)	1214 (365)	813 (188)	800 (72)	714 (266)	762 (261)
pH	6·80	7·19	7·04	7·38	7·07	7·14	6·92	6·80

Table II

Winter means of deposit matter (Tons per sq. Km. per month)

	Station							
	1	2	3	4	5	6	7	8
Total undissolved matter	198 (79)	525 (209)	295 (92)	1282 (157)	382 (205)	482 (143)	291 (102)	328 (143)
Tar (soluble in CS_2)	2 (1)	5 (3)	2 (2)	5 (8)	1 (2)	3 (3)	2 (2)	4 (5)
Insoluble ash	124 (47)	325 (158)	206 (69)	886 (475)	262 (153)	272 (138)	186 (81)	226 (115)
Combustible matter	72 (30)	195 (67)	87 (44)	391 (150)	119 (52)	207 (53)	102 (28)	98 (35)
Total soluble	192 (102)	446 (122)	290 (122)	1015 (556)	593 (413)	402 (207)	310 (120)	336 (153)
Ca^{++}	39 (33)	100 (64)	83 (71)	258 (47)	114 (65)	76 (64)	64 (28)	51 (20)
Cl^{--}...	12 (9)	17 (18)	14 (8)	20 (51)	15 (8)	15 (13)	8 (4)	9 (4)
SO_4^{--}	71 (33)	157 (65)	107 (55)	330 (199)	147 (60)	152 (60)	122 (52)	98 (25)
Total solids	390 (144)	972 (273)	585 (158)	2298 (868)	975 (464)	884 (308)	602 (183)	664 (236)
pH	6·69	7·17	7·03	7·88	7·24	6·91	6·86	6·83

matter in comparison with the characteristics of atmospheric pollution as determined in England. For example, in Padua the dissolved matter varies between 37 per cent and 55 per cent in summer time and between a minimum of 43 per cent and a maximum of 60 per cent in winter time. In England, according to Monkhouse, as reported by the DSIR, the dissolved matter is only of the 32 per cent of the total when pollution is heavy, while it is of about the 60 per cent in less polluted places.

Distribution of the different fractions in the controlled area is shown in Figs. 3, 4, 5, 6, 7, 8, where the contour lines represent mean values calculated for summer and winter months.

Distribution of pollution caused by sulphur dioxide in summer and winter months is graphically represented in Figs. 9 and 10.

At Padua, the ratio between the more and the less polluted areas is of 1:10 in summer, while it is of 1:2·5 in winter time, owing to the increased values for the residential quarters.

At Leicester, during the well-known investigations in 1937–'39 it has been noted how it could be possible to determine the distribution of winter values by multiplying the summer mean values for sulphur dioxide, obtained by the lead peroxide method, by the factor 2·4. This factor is different in Padua and it can be estimated to be between 5 and 8.

Thus, a more wide seasonal variation of the atmospheric pollution is demonstrated. This is mostly due to the different meterorological characteristics, which assure, during summer time, a stronger self-purification.

Data obtained from our research have brought a first useful contribution to a better knowledge of the local condition of atmospheric pollution. They were also of great help as a guide to the epidemiological study dealing with distribution of the diseases of respiratory apparatus among urban population, which we have presently in progress.

Unfortunately we must realize how they were not much taken into account on planning the future urban extensions of our towns.

Table III
Means of sulphur dioxide
(mg SO_3/day/100 cm^2)

Station	*Summer means*	*Winter means*
1	0·21 (0·15)	0·93 (0·68)
2	0·63 (0·12)	0·77 (0·57)
3	1·99 (0·79)	1·81 (1·07)
4	0·41 (0·14)	2·53 (1·27)
5	0·30 (0·11)	1·70 (0·66)
6	0·31 (0·12)	2·20 (0·10)
7	0·38 (0·08)	2·32 (1·13)
8	0·25 (0·05)	1·60 (0·70)

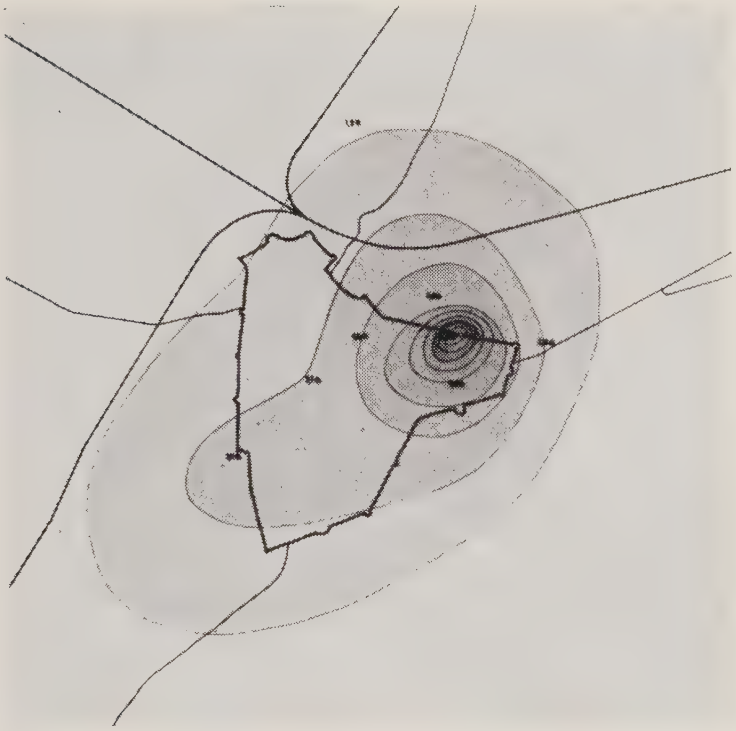

Fig. 3. *Total soluble matter—winter*

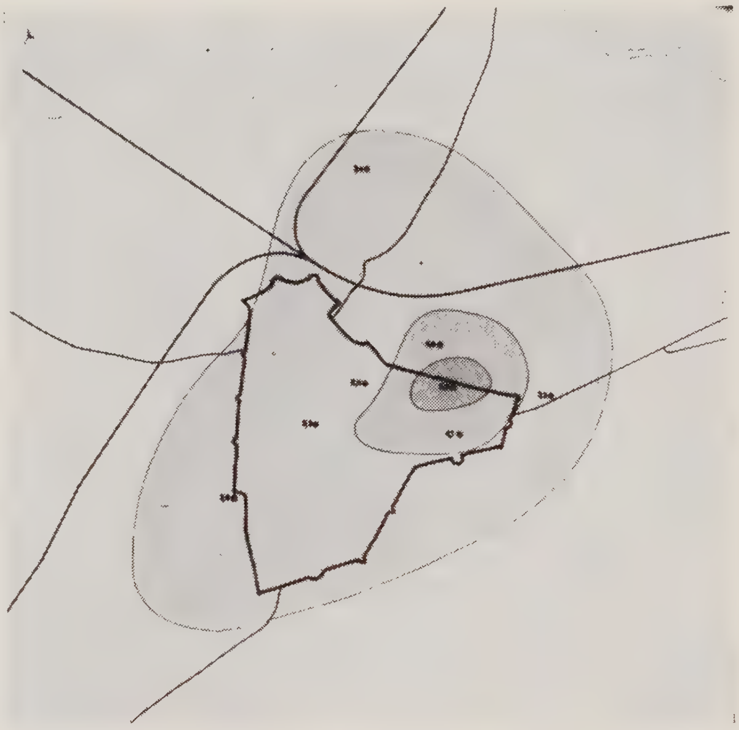

Fig. 4. *Total soluble matter—summer*

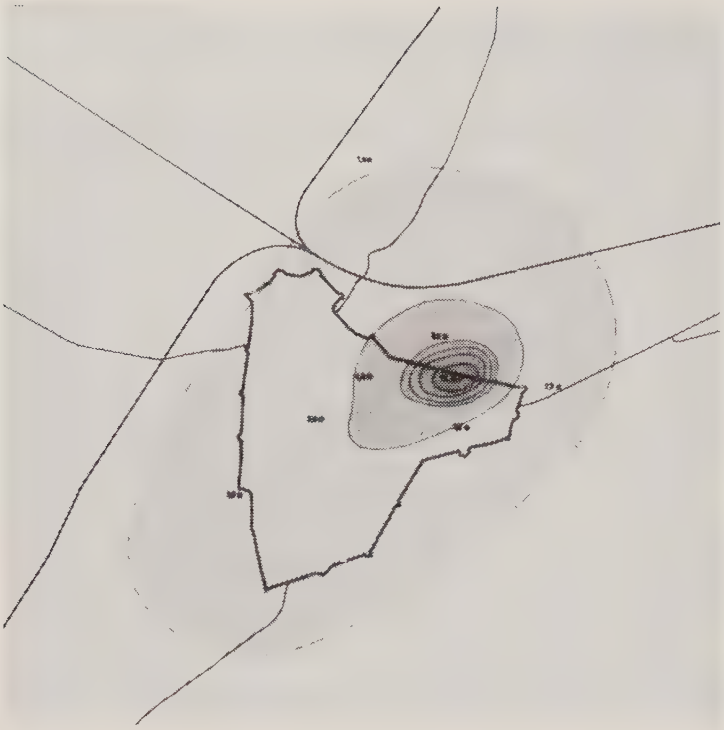

Fig. 5 *Total insoluble matter—winter*

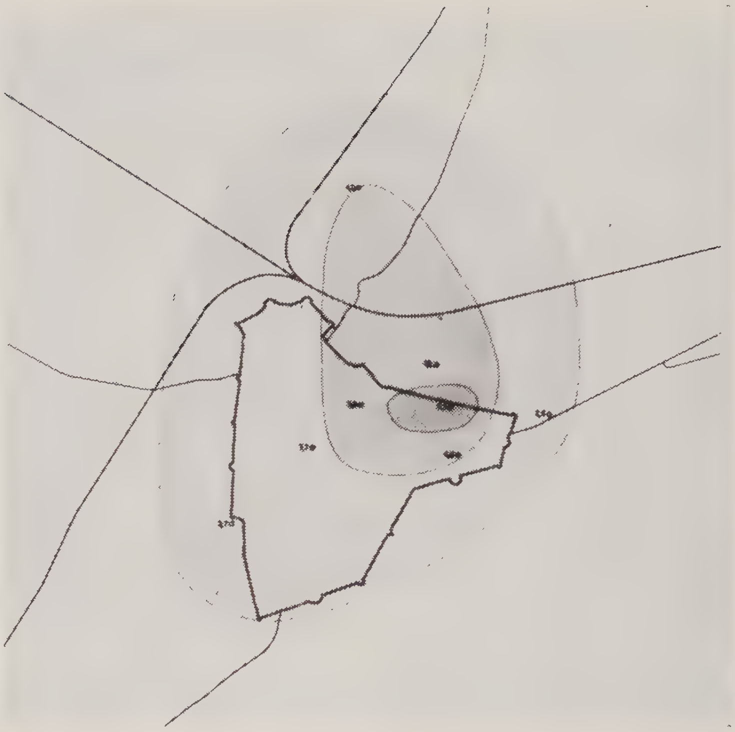

Fig. 6 *Total insoluble matter—summer*

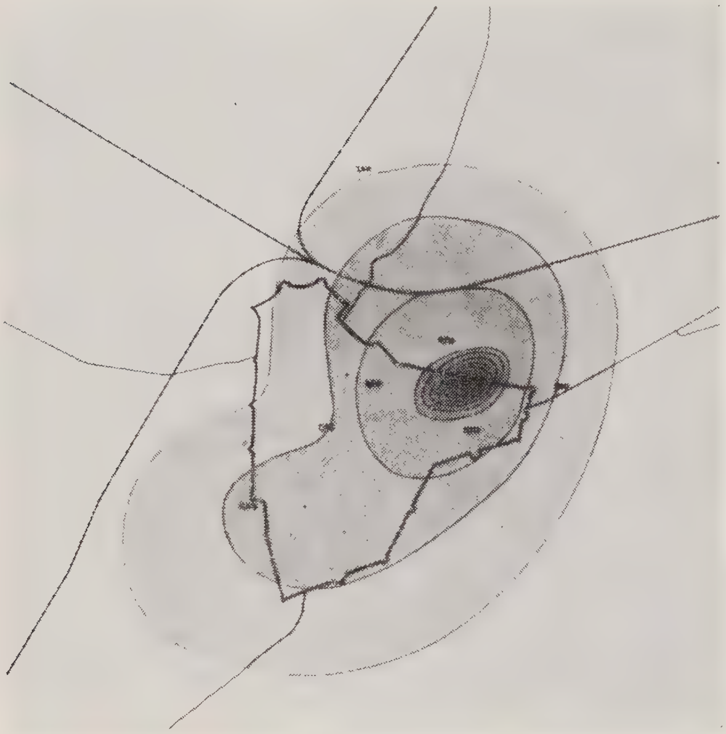

Fig. 7 *Total solids—winter*

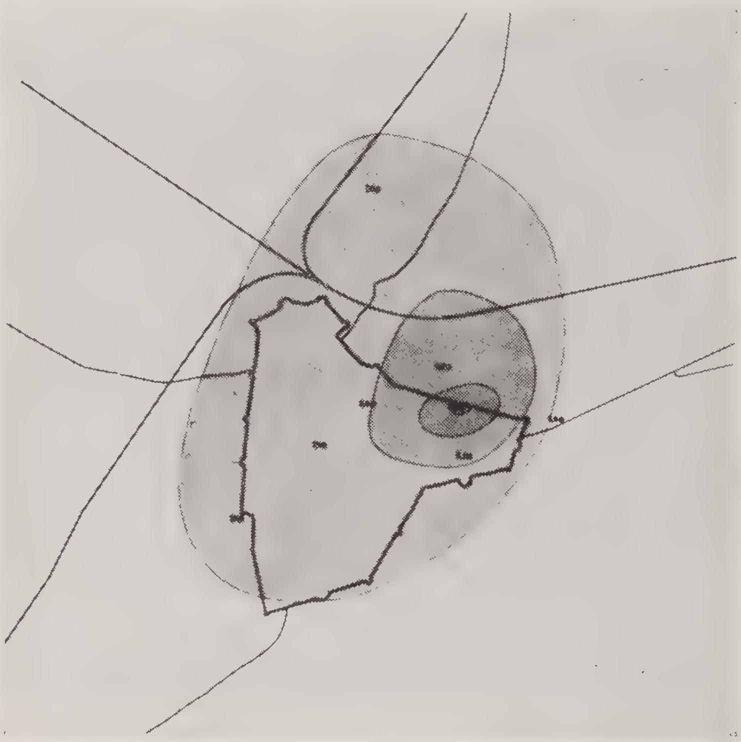

Fig. 8 *Total solids—summer*

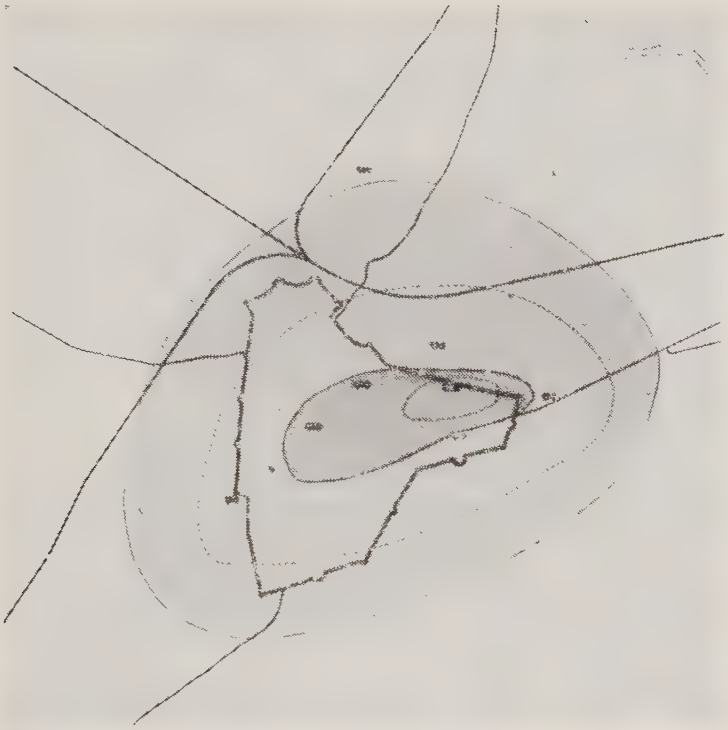

Fig. 9 *Sulphur dioxide—winter*

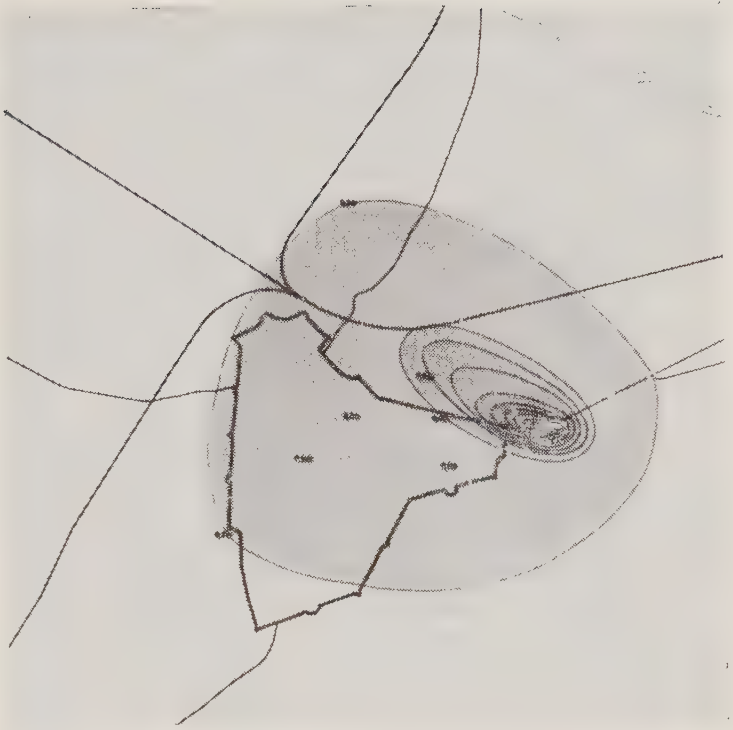

Fig. 10 *Sulphur dioxide—summer*

IV. 55

AIR POLLUTION IN THE CITY OF GENOA (ITALY)

Professor FERNANDO LUIGI PETRILLI, Director of the Hygiene Institute of the University of Genoa (Italy).

SUMMARY: Air pollution in the city of Genoa has been studied since November 1954 by the Institute of Hygiene of Genoa University of which the author is Director. The apparatus and equipment used are as advised by the British D.S.I.R. The paper describes the geographical and meteorological characteristics of the city and continues by describing the various air pollution sources. The researches have shown that sulphur dioxide in the residential districts is negligible and although higher in the industrial areas is not yet comparable to those in other foreign industrial towns. Pollution by iron dust is also low in the residential districts but peaks have been reached in the industrial areas comparable to foreign towns with ironworks and engineering works. Suspended dust remains within modest limits. Carbon monoxide does not reach high concentrations except in vehicular tunnels. The city is fortunate in that the meteorological and topographic conditions create a condition favourable for the dispersion of polluting substances. The paper is accompanied by a diagram and a number of tables.

Air pollution in the city of Genoa has been ever since November 1954 the object of researches and studies carried out by the Institute of Hygiene of Genoa University, of which I am the Director.

The researches which were limited at first to a hospital area, were extended during the last four years to the whole territory of the municipality of Genoa. As the apparatus and equipment employed for the continuous sampling of air are as advised by the British D.S.I.R., I think it interesting to report herewith the main results reached in the study of air pollution due to very fine dust both deposited and suspended and also to gas.

The city of Genoa which spreads over 34,477 hectares (about 85,193 acres), of which about 5,000 hectares (12,355 acres) are densely inhabited, is bounded south by the Mediterranean Sea and north by the Ligurian Apennines very close to the city. The urban districts are compressed along a strip some 33 kilometres long, and penetrate into the hinterland along the valleys of the two main torrents: the Polcevera and Bisagno, ending eastwards and westwards where two well know summer and winter resorts, Nervi and Pegli, are situated.

The main industries of Genoa (steel works, engineering works, petroleum refineries, shipyards, etc.) are located along the western part of the city and in the Polcevera valley, whereas the residential districts are spread along the eastern section of the city. The level of the city varies between 0 and 350 metres above sea level.

The anemologic regime is characterized, during the winter months, by north winds which often blow at over 20 m.p.h. In summer light and moderate south and west winds prevail, with sea–land or land–sea breezes flowing along the two above-mentioned valleys. Rainfall reaches its peak in autumn, with an average of 106 rainy days and 1,200 mm of rainfall per annum.

The areas shown in the following tables, and to which the mean results of our researches refer, are the following:

Area I:	suburban residential districts;
Area II:	middle-eastern residential districts;
Area III:	middle-western districts mainly almost at sea level and near metallurgical and iron industries;
Area IV:	hilly middle-western districts north of Area III;
Area V:	districts located along the Polcevera valley at more than 1,500 metres (about 1 mile) from the sea-shore, where petroleum-refineries prevail.

The atmospheric pollution sources are:

(a) Domestic heating plants, working on average from the end of October till March.

(b) Motor-traffic: particularly intense in the centre of the city because of lack of circumvallation or circuit streets so that all transit of vehicles must take place through the central streets.

(c) Industrial factories: steel-works, coke plants, and foundries (Area III). Petroleum refineries (Area V).

On the whole our researches have shown:

In connection with sulphur dioxide the continuous samples as well as the intermittent ones revealed nothing worth worrying about in the mainly residential Areas I and II, where we can only notice a greater quantity of this gas during the cold season.

In the industrial areas the phenomena of seasonal variations is less apparent, but the levels reached, by far greater, are not yet, however, comparable to those ascertained in other foreign industrial towns. (See Tables I and II.)

Peaks were ascertained in the areas neighbouring the petroleum refineries. The pollution by fine dust deposited in the residential districts in the centre of the city, is very little different from that in the districts on the outskirts, but there is a remarkable difference noticeable in the industrial districts (Areas III and IV) where peaks have been reached not much different from those ascertained in foreign towns with iron works and engineering works.

A particular feature of such type of pollution is represented by the particles of iron which characterize Areas III and IV as could be expected.

The maximum quantities of fine dust settling in districts are to be found in the plain next to the iron and steel works where it reaches a quantity almost double that in the corresponding hilly area. (See Tables III and IV.)

The fine dust in the air (suspended matter) both in the residential districts and in the industrial ones remains within modest limits (see Table V). Carbon monoxide does not reach a high concentration in the streets but in the tunnels (Genoa has many of them) when in the rush hours the traffic is heavy this gas can reach severe concentrations. (See Table VI.)

The above are the most interesting features of the researches carried out. With regard to particular problems such as the presence of compounds which may cause cancer, the data so far collected are not yet sufficient to be worthy of note.

If we wish to sum up the situation after more than five years from the beginning of our researches we could say that, fortunately, the meteorological and topographic conditions in the city of Genoa create a condition relatively favourable for the dispersion of polluting substances. Where such favourable conditions cannot exist, as in some areas next to iron and steel industries and petroleum refineries and in tunnels where road traffic is intense, we reach sometimes such a degree of pollution as to make it necessary to adopt some suitable preventive measure to reduce all or most of the consequent inconveniences.

Table I

SULPHUR DIOXIDE

Measurements by the Lead Peroxide Instrument (D.S.I.R.) (SO_2, mg/100 cm^2/day)

	Area I	*Area II*	*Area III*	*Area IV*	*Area V*
April–September 1956	0·10	0·19	—	—	—
October 1956–March 1957 ...	0·29	0·46	0·80	1·38	1·37
April–September 1957	0·09	0·19	0·89	1·01	1·31
October 1957–March 1958 ...	0·26	0·56	0·88	1·61	2·18
April–September 1958	0·10	0·16	0·92	0·92	0·95
October 1958–March 1959 ...	0·31	0·45	1·02	1·04	2·52
April–September (average) ...	0·096	0·18	0·90	0·96	1·13
October–March (average) ...	0·28	0·49	0·90	1·34	2·02
April 1956–March 1959 (average)	0·19	0·33	0·90	1·19	1·66

Table II

SULPHUR DIOXIDE

Measurements by portable apparatus: Mean daily averages (SO_2, parts per million)

	Area I	*Area II*	*Area III*	*Area IV*	*Area V*
April–September 1956	0·001	0·012	0·094	0·125	0·165
October 1956–March 1957 ...	0·009	0·031	0·107	0·151	0·355
April–September 1957	0·001	0·010	0·110	0·140	0·163
October 1957–March 1958 ...	0·008	0·041	0·099	0·143	0·288
April–September 1958	0·001	0·012	0·102	0·120	0·138
October 1958–March 1959 ...	0·009	0·035	0·104	0·137	0·315
April–September (average) ...	0·001	0·011	0·102	0·128	0·155
October–March (average) ...	0·009	0·036	0·103	0·143	0·319
April 1956–March 1959 (average)	0·004	0·023	0·102	0·136	0·237

Table III

WATER-INSOLUBLE DEPOSITED MATTER

Measurements by standard deposit gauges (D.S.I.R.) (g/100 m^2/month)

	Area I	*Area II*	*Area III*	*Area IV*	*Area V*
April–September 1956	299	222	—	—	—
October 1956–March 1957 ...	157	243	1,238	533	426
April–September 1957	233	237	2,009	891	404
October 1957–March 1958 ...	144	283	1,035	541	448
April–September 1958	273	467	1,659	840	493
October 1958–March 1959 ...	130	294	816	359	502
April–September (average) ...	268	308	1,834	865	448
October–March (average) ...	143	273	1,029	477	458
April 1956–March 1959 (average)	206	291	1,351	632	454

Table IV

IRON (Fe_2)

Measurements in the water-insoluble matter collected by standard deposit gauges (D.S.I.R.) (g/100 m^2/month)

	Area I	*Area II*	*Area III*	*Area IV*	*Area V*
April–September 1957	65	36	373	415	95
October 1957–March 1958 ...	19	24	172	92	58
April–September 1958	40	31	259	160	76
October 1958–March 1959 ...	18	29	275	158	44
April–September (average) ...	52	33	316	287	85
October–March (average) ...	18	26	223	125	51
April 1957–March 1959 (average)	35	30	269	206	68

Table V

ATMOSPHERIC SUSPENDED MATTER

Measurements by portable apparatus: Mean daily averages (mg/m^3)

	Area I	*Area II*	*Area III*	*Area IV*	*Area V*
April–September 1956	0·15	0·27	0·35	0·38	0·30
October 1956–March 1957 ...	0·21	0·53	0·28	0·24	0·24
April–September 1957	0·13	0·27	0·36	0·40	0·29
October 1957–March 1958 ...	0·20	0·65	0·26	0·23	0·25
April–September 1958	0·12	0·25	0·34	0·38	0·29
October 1958–March 1959 ...	0·22	0·43	0·28	0·27	0·25
April–September (average) ...	0·13	0·26	0·35	0·38	0·29
October–March (average) ...	0·21	0·53	0·27	0·24	0·25
April 1956–March 1959 (average)	0·17	0·40	0·31	0·30	0·27

Table VI

CARBON MONOXIDE

Highest concentrations measured in a tunnel in Area II (1959) (Parts per million)

Hour	*CO (ppm)*	*Intensity of traffic*
6 a.m.	13	light
7 a.m.	18	light
8 a.m.	150	heavy
9 a.m.	39	medium
10 a.m.	75	medium
11 a.m.	400	heavy
12 a.m.	350	heavy
1 p.m.	125	heavy
2 p.m.	325	heavy
3 p.m.	300	heavy
4 p.m.	200	heavy
5 p.m.	175	heavy
6 p.m.	150	heavy
7 p.m.	200	heavy
8 p.m.	325	heavy
9 p.m.	150	heavy
10 p.m.	50	medium
11 p.m.	23	light
12 p.m.	48	light

NEW DATA ON MAXIMUM ALLOWABLE CONCENTRATIONS OF POLLUTANTS IN THE AIR IN THE U.S.S.R.

PROF. A. V. RIASANOV, Doctor of Medical Sciences, Chairman of Medical Control Committee on Air Pollution of the State Medical Commission.

SUMMARY: The author points out that the actions of poisonous agents on the human body become inoperative below a definite limit of concentration. This being so, it is only necessary to reduce air pollutants to below the limit at which they become harmful. Russian investigators have set out to determine these limits by conducting experiments on animals, by comparing the changes in human beings living in polluted areas with those living in clean areas, and by carefully controlled laboratory experiments with human subjects. The most rewarding of the results from the last type of experiment have been obtained by demonstrating the reaction of the bioelectric impulses in the brain to quantities of pollutants undetectable by the nose. When fixing maximum concentrations the effects on vegetation, materials and atmospheric clarity are taken into account. Also of great importance are (1) defensive reactions of the body (showing that condition are not at the optimum,) (2) that any stimulant is undesirable if it operates against a person's free-will. (3) the maximum permissible concentration should be set by reference to the most sensitive index. On the basis of these considerations a tentative table of maximum concentrations for 30 pollutants has been produced and is appended to the paper.

The investigations of soviet hygienists in elaborating values for maximum permissible concentrations of noxious substances in the atmosphere are based upon the principle that the action of each poisonous agent on the human body is determined not only by its quantitative but also by its qualitative concentration. By reducing the concentration of the intoxicating substance we, finally, reach a limit below which this substance can no longer exercise any deleterious or unfavourable effect upon the human body and becomes quite indifferent for the latter.

Since this appears to be a generally accepted rule there is no sense in demanding absolute purity of the air in our cities but it is sufficient to reduce the concentration of harmful agents to a limit when they become harmless and indifferent to the human body. Such a formulation of the problem will spare us the necessity of incurring huge additional expenses, which are practically needless.

But here the question arises—how to determine the limit below which the poisonous agents become indifferent for the human body ?

To do this we follow three different courses:

1. The study under experimental conditions of the chronic effect exerted on the animals by extremely small concentrations of the noxious substances, whereby —to disclose the deleterious effect—highly sensitive methods are being employed. These include the study of the changes in the higher nervous activity in the animals by the conditioned reflex method, or by that involving the investigation of subordinated chronaxie; the study of delicate histological changes in the cerebral cortex while staining the preparations according to Golgi; the study of certain biochemical changes, such as, for instance, the spectrophotometric observations of the porphyrin exchange; the investigation of the cumulation of noxious agents in the body, etc.

2. The study of physiological and biochemical shifts occurring in the body of humans inhabiting areas with polluted atmosphere, as contrasted with the districts where the air pollution does not exceed the limits of the maximum permissible concentration proposed by us.

3. The study under strict experimental conditions of the acute effect of poisonous and stimulating substances used in very small concentrations, so as to determine the threshold of the reflex changes in the body.

It is well known that irritants during their inspiration produce various reflex reactions, such as: cough, epiphora, sternuation. Alongside these reflexes, which are evident to everyone, there also occur latent reflex reactions, which become apparent only as the result of special methods of investigation. Thus, for example, there appear alterations in the volume and rate of respiration, in the tonicity of the cutaneous blood vessels, and in the functional condition of the human cerebral cortex.

Particularly great attention we attach to the reflex changes in the higher nervous activity. We study the effect of very low concentrations of noxious agents upon the light sensitivity of the eye, on the optical chronaxie and on the cerebral biocurrents. The lastly named method proved to be particularly sensitive.

Essentially it consists of the following : if in a dark, isolated room harbouring a person placed in a comfortable position a light is suddenly turned on—the electroencephalogram of the individual under observation will show changes involving reflex inhibition of the alpha waves, or, as it is said, desynchronization of the alpha-rhythm. This reflex is unconditioned. The person under observation inspires pure air, which is being furnished immediately to his nose. From the adjacent room with a control panel one can add at any time to the pure air quite imperceptibly the substance under study in such a concentration, which in itself would not provoke any desynchronization of the alpha-rhythm. If now the inspiration of the agent under study be combined with the turning on of the light this would very quickly lead to the elaboration of a conditioned reflex and the substance under study would commence to provoke desynchronization a few seconds prior to the switching on of the light. This conditioned reflex, which we call electro-cortical conditioned reflex, appears very quickly—after 5–8 combinations of light flashes with the inspiration of the substance under study. It bears witness to the effect that the agent under study exercises certain effect on the cortex of cerebral hemispheres. By varying the concentration of the substance inspired we manage to find the threshold below which this reflex is no longer elaborated.

The sensitivity of this method may be illustrated by the following data obtained by my collaborator Gofmekler while studying the butyl acetate:—

Odour threshold for most sensitive individuals—0·6 mg/M3.

The threshold of reflex changes in the light sensitivity of the eye—0·3 mg/M3.

The threshold characterizing the appearance of the electrocortical reflex—0·13 mg/M3.

In the instance of sulphur dioxide my collaborator Bushtueva obtained the following data:

Odour threshold—1·6—2·6 mg/M3.

The threshold of reflex changes in the light sensitivity of the eye—0·92 mg/M3.

The threshold characterizing the appearance of the electrocortical reflex—0·6 mg/M3.

The above experiments demonstrate that the method involving the production of the electrocortical conditioned reflex is a great deal more sensitive than those employed by us before, and that the concentration of certain noxious agents, imperceptible by their odour, can provoke in man reflex changes in the condition of the cerebral cortex.

As the result of all these investigations we have established two indices: the maximum permissible one-time/single concentration and the maximum permissible average daily concentration. The purpose of the first is to prevent the possibility of any reflex changes during inspiration of short duration, while the second should avert the possible chronic effect following prolonged inspiration.

When fixing maximum permissible concentrations we also take into account certain other points, viz, the influence upon vegetation, corrosion of various metals, the effect on the limpidity of the atmosphere, etc.

Allow me to point out here certain general principles which we consider to be of a particularly great importance:

1. When fixing the maximum permissible concentrations of foreign substances in the atmosphere we must consider not only their deleterious influence upon the body, but also the appearance of diverse defensive reactions and compensatory processes. Their presence testifies to the fact that the external environment does not conform with the physiological optimum, i.e. it fails to satisfy hygienic requirements.

2. Any stimulant or irritant, disagreeable or agreeable for man, becomes disagreeable, intolerable and even harmful as soon as it begins to act upon him in spite of his desire and continues to do so against his free will.

3. The maximum permissible concentration should be set by using the index, which proved to be most sensitive for the given concrete substance.

Using the above principles as the basis, we, in the USSR, have now established maximum permissible concentrations for 30 different substances. A number of changes have also been made following investigations of a later date, and are included in the table attached.

We are fully aware of the imperfect nature of the table, and consider it as a temporary one. We go on with the work involving checking up of previously made proposals, their correction and more precise definition. We also continue widening the lists of the types of pollutions, this being particularly important now, when, because of the growing polymers productions, an ever increasing number of new substances begin to be thrown out into the atmosphere. This work involves participation of many research establishments of our country, which is being headed by the Committee for sanitary protection of the atmospheric air.

The maximum allowable concentrations of an air pollutant to be used for hygienic evaluation of the air in populated areas

Air pollutant	Maximum allowable concentration (mg/m^3)	
	Max. concentration at one time	Average during 24 hours
1. Acrolein	0·3	0·1
2. Amyl acetate	0·1	—
3. Arsenic and its inorganic compounds (as As)	—	0·003
4. Benzene (Bensol) ...	2·4	0·8
5. Benzine (as C) ...	5·0	1·5
6. Butyl acetate	0·1	—
7. Carbon disulphide ...	0·03	0·01
8. Carbon monoxide ...	6·0	2·0
9. Chlorine	0·1	0·03
10. Chloroprene	0·25	0·08
11. Dichlorethane ...	3·0	1·0
12. Dust (nontoxic) ...	0·5	0·15
13. Ethyl acetate	0·1	—
14. Fluorine and its compounds (as F) ...	0·03	0·01
15. Formaldehyde ...	0·035	0·012
16. Hydrogen chloride ...	0·05	0·015
17. Hydrogen sulphide ...	0·03	0·01
18. Lead and its compounds (as Pb) ...	—	0·0007
19. Lead sulphide ...	—	0·0017
20. Manganese and its compounds (as Mn)	0·03	0·01
21. Mercury	—	0·0003
22. Methanol	1·5	0·5
23. Methyl acetate ...	0·07	—
24. Nitrogen oxides ...	0·30	0·10
25. Phenol	0·3	0·1
26. Phosphorus anhydride	0·15	0·05
27. Soot	0·15	0·05
28. Sulphuric acid ...	0·3	0·1
29. Sulphur dioxide ...	0·5	0·15
30. Vinyl acetate ...	0·2	—

IV. 57

RESEARCH INTO ATMOSPHERIC POLLUTION IN THE CITY OF ESSEN

Dr. ING. K. SCHWARZ, Dipl. Phys. T. GILBERT, and Dipl. Phys. E. RATZKI, Germany

SUMMARY: From November 1955 to February 1957, the Technischer Uberwachungs-Verein Essen e.V. carried out a series of measurements of dust deposition at 600 measuring points in the urban area of Essen, using the Diem sticky plate method. For comparison, each of the collectors used by the City of Essen since 1932 was supplemented by a sticky plate and a third type of gauge. A comparison of the results obtained with the various types of apparatus is given, together with some specimen maps of dust deposition in the city.

From November 1955 to February 1957, the Technischer Uberwachungs-Verein Essen e.V. carried out a series of measurements of dust deposition at 600 measuring points in the urban area of Essen (180 sq. km.), using the Diem sticky plate method [1]. For a comparison of the results obtained with the readings previously recorded in Essen since 1932 by means of the Liesegang/Löbner dust-collector [2], each of the Liesegang collectors operated by the City of Essen (Fig. 1) at 15 of the city's measuring centres was supplemented by a sticky plate (Fig. 2) and a dust-collecting gauge of the type developed by Hibernia (Fig. 1).

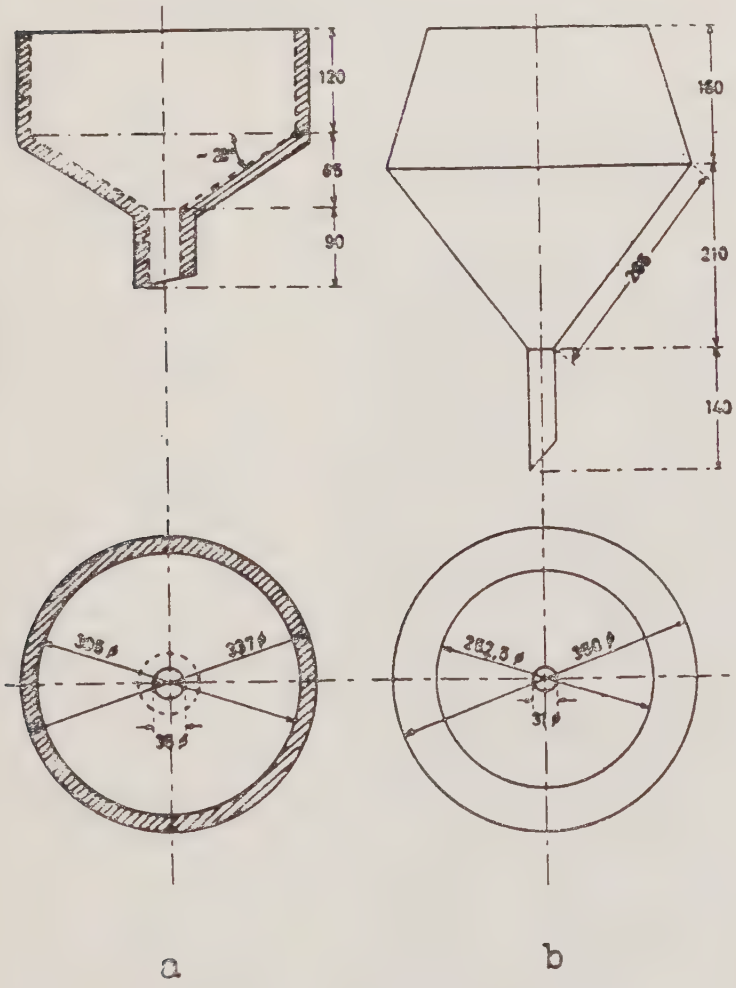

Fig. 1 Dust-collecting gauges
(*a*) *Liesegang type* (*b*) *Hibernia type*

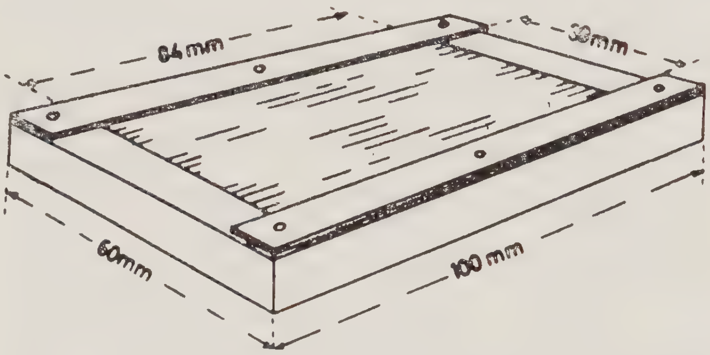

Fig. 2 Diem sticky plate, with frame

Comparison of results obtained with the various types of apparatus

Owing to the different methods of measurement and evaluation used with the three types of apparatus, the data obtained are not fully comparable. Whereas the quantity of dust deposited as measured by the sticky plate system can be measured directly by weighing before and after exposure, in the case of the collector gauge the undissolved dust must be filtered out and, in addition, the collected liquid is evaporated to determine the quantity of other substances contained in it and the residue is subjected to chemical analysis.

Thirty-eight individual results are available for purposes of this comparison. Generally speaking, the largest quantity of dust collected was recorded with the Hibernia gauge. The individual measurements of insoluble matter filtered out vary—

with the Hibernia gauge from 4·1 to 47·6 gr/m^2 per 30 days;

with the Liesegang gauge from 2·2 to 41·1 gr/m^2 per 30 days.

For comparison, the quantities of deposit collected on the sticky plate vary from 2·1 to 37·3 gr/m^2 per 30 days.

For the soluble matter alone, the values vary—

with the Hibernia gauge from 5·3 to 25·3 gr/m^2 per 30 days;

with the Liesegang gauge from 2·1 to 11·8 gr/m^2 per 30 days.

For insoluble and soluble matter combined, the readings vary from—

10·5 to 62·2 gr/m^2 per 30 days with the Hibernia type; and

5·6 to 46·5 gr/m^2 per 30 days with the Liesegang gauge.

The quantity of rain as measured with the latter averaged 107 per cent of that measured with the Hibernia gauge.

Comparison of individual measurements

The individual measurements obtained at each measuring point are compared in the attached graphs.

In Fig. 3, comparing the insoluble matter filtered out from the Hibernia and the Liesegang gauges, the biggest concentration is beneath the 45° line. Independently of the insoluble matter content, the Liesegang gauge invariably recorded smaller values than the Hibernia at undisturbed measuring points.

The amount of soluble matter measured with the Liesegang gauge (evaporation residue) (Fig. 4) is in

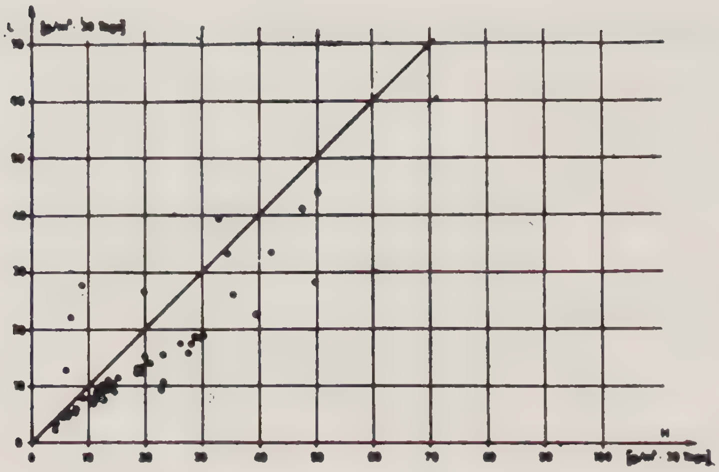

Fig. 3 *Hibernia-Liesegang comparison*
H–Hibernia, filter residue *L–Liesegang, insoluble matter*

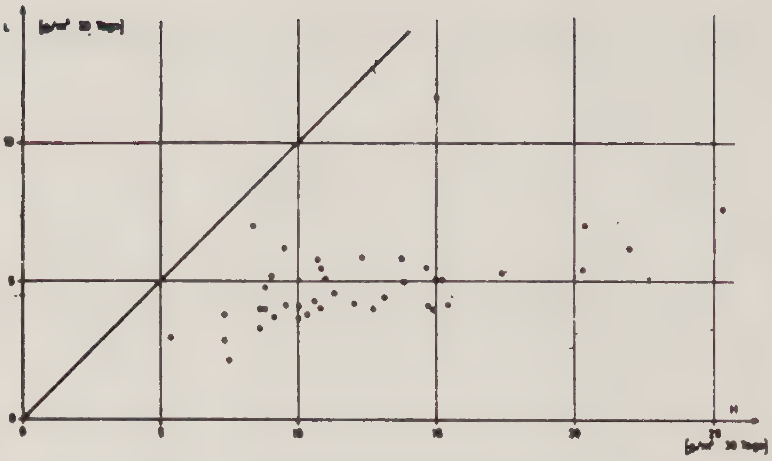

Fig. 4 *H—Hibernia (evaporation residue)*
L–Liesegang (soluble matter)

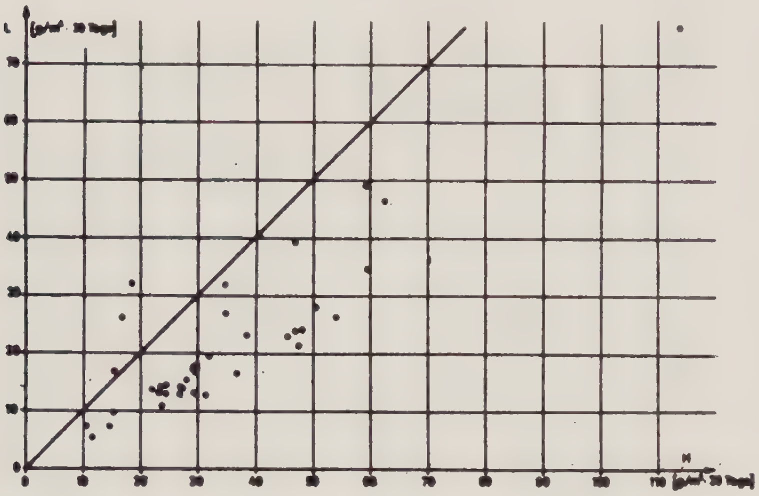

Fig. 5 *H–Hibernia (filter residue plus evaporation residue)*
L–Liesegang (insoluble plus soluble matter)

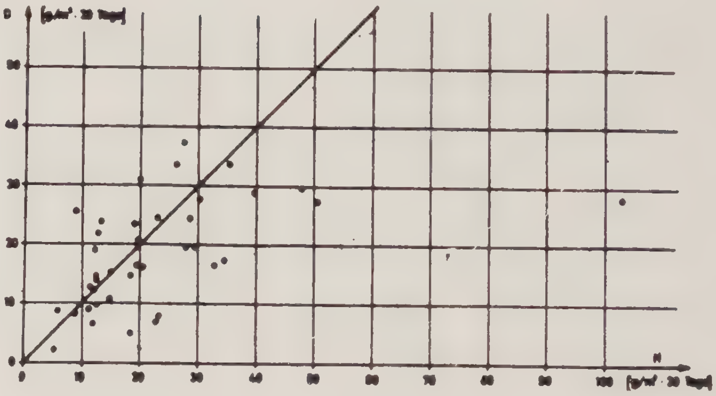

Fig. 6 *Hibernia/Diem comparison—*
H–Hibernia (filter residue)
D–Diem (dust captured)

every case smaller than that given by the Hibernia. The measurements taken with the two types vary to different extents. While the Hibernia readings vary from 8 to 22 gr/m^2 per 30 days, with the Liesegang they mostly lie between 3·5 and 6 gr/m^2 per 30 days.

As regards the total of soluble and insoluble matter (Fig. 5), most of the Liesegang measurements give much lower values than the Hibernia as in the above comparisons relating to insoluble and soluble matter separately.

In contrast, the comparison between the Hibernia gauge and the Diem sticky plate (Fig. 6) gives quite a different picture. Compared with the filter residue weights of the Hibernia measurements there is a much greater scatter of the values. However, they are fairly evenly distributed on either side of the 45° line. The sticky plate values are all smaller only in the case of residues of over 40 gr/m^2 per 30 days, due to reduced capturing capacity of the plate.

Compared with the total soluble and insoluble matter as determined with the Hibernia gauge, the quantities collected on the sticky plate are too low. This can be attributed to the fact that only insoluble matter is retained by the plate.

Comparison of total quantities

Taking the amounts of dust collected at individual measuring points by the Hibernia gauge as 100 per cent, and confining attention to undisturbed measurements where the sticky plate also gave valid results, the average amounts of insoluble matter measured with the Liesegang vessel amounted to 72·5 per cent.

The soluble matter from the water collected in the Liesegang gauge amounted to only about 40 per cent of the corresponding Hibernia values. The total of insoluble matter and soluble matter measured with the Liesegang apparatus averaged only about 60 per cent of the Hibernia figures.

It seems that the different height and shape of the gauges are responsible for the relatively large and regular differences in dust deposition as measured with the two types of collector.

On the other hand, the quantities of dust measured with the sticky plates approach much more closely to the amounts of insoluble matter collected with the Hibernia gauge. As regards comparable readings, the average relationship is 93·3 per cent. For dust deposition rates up to about 35 gr/m^2 per 30 days, the average difference between the results obtained by the two methods is small (Fig. 6). For higher rates of deposition, the difference is greater. The capturing capacity of the plate evidently becomes exhausted at higher readings. Better results could be obtained if the plates were changed more frequently.

The possible influence of meteorological conditions on the results obtained with the various methods of measurement cannot be judged, in view of the short time over which observations were taken.

Dust deposition maps of the City of Essen

For the Technischer Uberwachungs-Verein Essen research programme, simplicity and low cost were the prime consideration in view of the large number of measuring points scattered throughout the area; hence, the Diem sticky plate method was chosen. The individual readings taken at each measuring point were converted to monthly totals or totals for periods of roughly the same weather (in gr/m^2 per 30 days) and plotted on maps of the city area. Areas with different levels of dust deposition were mapped out. Such dust deposition maps for single months or other periods show that considerable local differences exist within the area investigated, and that the results depend largely on weather conditions and especially wind direction and rainfall. Needless to say, they relate only to the particular month in question or to similar weather conditions, and cannot be applied to the corresponding period of another year. A similar distribution of dust deposition would only be likely to occur under identical weather conditions and the same emission of pollutants.

The attached maps Figs. 7, 8 and 9 should be regarded as *specimens* only.

Northerly winds

In April (Fig. 10) cold, unsettled weather prevailed, due to several strong currents of icy air from the northern plains. The dust deposition map corresponds to the prevailing northerly winds. Dust from the highly industrialized districts in the north of the city and adjacent industrial towns to the north was carried far to the south, and the amounts deposited in the north-eastern part of the city were almost invariably in excess of 50 gr/m^2 per 30 days.

Conversely, in the less industrialized southern and western districts where the air is initially cleaner, the rates of deposition mainly varied between 20 and 50 gr/m^2 per 30 days.

High pressure conditions with easterly winds

From 8th to 21st March, 1956, Central Europe was on the southern edge of a zone of high pressure in a cold airstream from the east, and the weather was dry and fine. The deposition map (Fig. 8) shows areas with high and low rates of dust deposition which are very close together. In the main, this was probably a result of the dry weather associated with high barometric pressure. Local conditions then have considerably more effect, and an increase in deposition as a result of dust raised at rubbish dumps, building sites, etc., and also that caused by traffic becomes more apparent.

Southwest wind

In October 1956 (Fig. 9), the weather was very variable. During the month, which was very rainy (181 per cent of the normal figure) with southwesterly winds prevailing, only a few small areas in the north showed a dust deposition above 50 gr/m^2 per 30 days. In this case, dust originating within the city from the less industrialized south-western districts is slight.

These maps showing the distribution of dust deposition make it possible to evaluate the rate of deposition in the area investigated. You may assume an average deposition in the northern part of about 50 gr/m^2 per 30 days, in the southern part of less than 30 gr/m^2 per 30 days. Maximum and minimum figures above and below these averages depend upon meteorological and orographic conditions and the influence of local sources of pollution.

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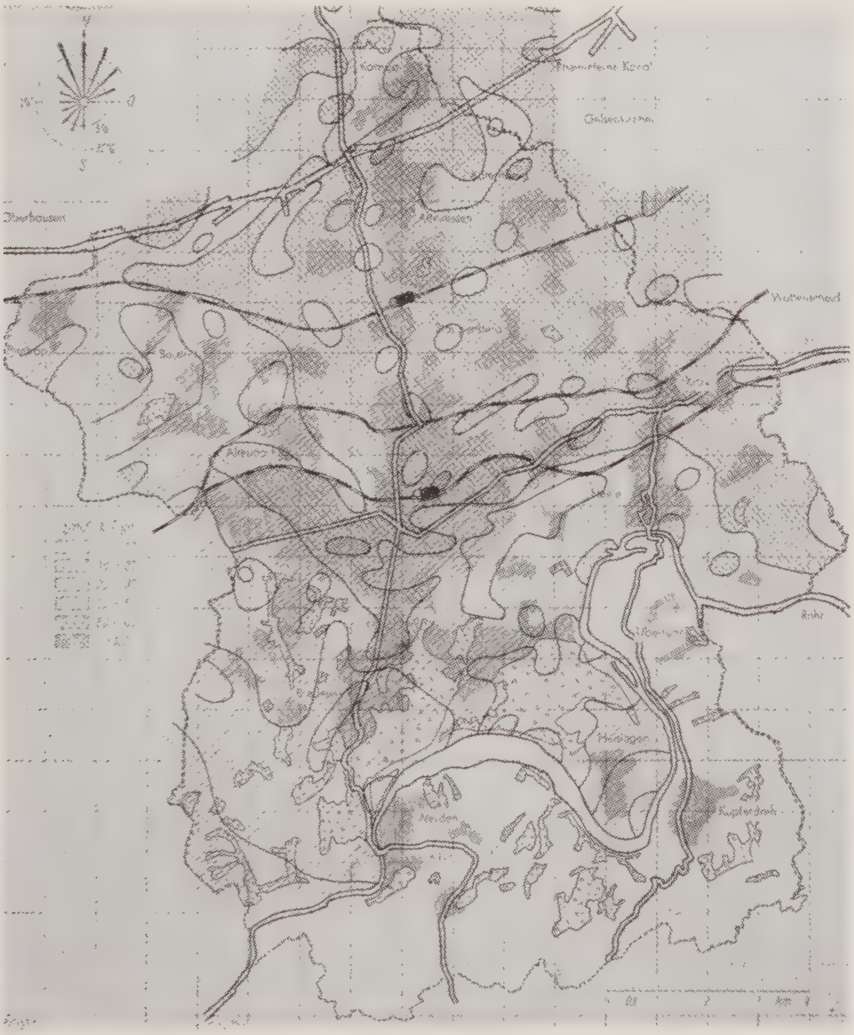

Fig. 7

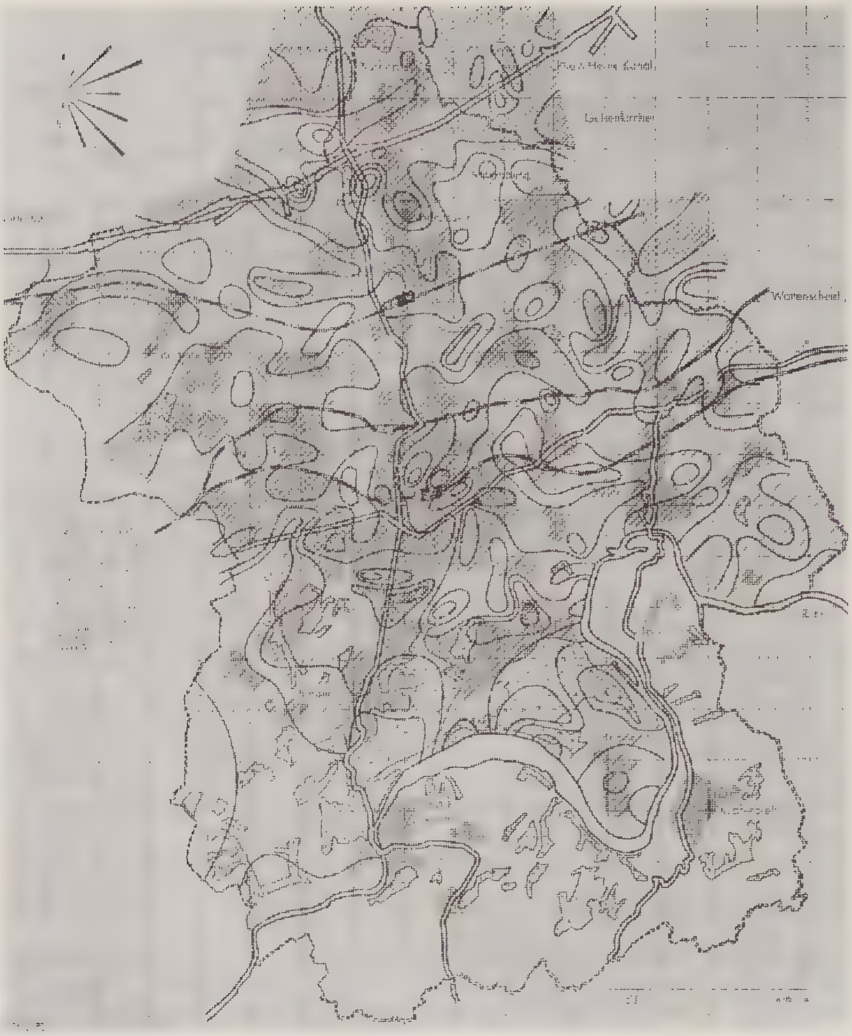

Fig. 8

IV. 58

DETERMINATION OF PARTICLE SIZES IN INDUSTRIAL AEROSOLS OF THE CITY AIR

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SUMMARY: In measuring the aerosols present in the air of Prague a combination of sedimentation and diffusion methods was found most suitable. Fine and middle aerosol fractions were retained for examination under the electron microscope by diffusion on fibrous crystals of copper oxide. Large fractions were retained for examination by optical microscope by sedimentation on vaseline coated slides. It is concluded that these methods are superior to thermal or electro-precipitator methods.

Introduction

In order to study the effects of various air-contaminants on human health as well as the mechanism of the biological and physical-chemical effects of these harmful pollutants, we use physical and biological methods. With regard to contaminants occurring in the form of aerosols, we must determine more exactly by means of chemical and physical investigation, their quality and quantity, namely the concentration, the shapes and size of aerosol particles, the quality of their surface area, their chemical and mineralogical composition, etc.

Methods used for the determination of these characteristics of the particles are rather intricate, therefore they are not applicable in the field-technique. There is a difficulty even in aerosol sampling if aerosol particles in the air borne state are to be captured and the size of the particle is at least $0{\cdot}05$–50μ.

For sampling of aerosol particles and their observation under the electron microscope (particle sizes ranging from $0{\cdot}05$–3μ) the thermal precipitator[1, 2, 3] or the electrostatic precipitator[6] are used to advantage. The preparation of formvar films as well as sampling of aerosols is very slow and in this manner we capture the middle aerosol fraction only, while the coarse aerosol fraction—approximately particles ranging from 3–50μ—is not retained. In the other alternative when using the sedimentation methods[4] only, we sample only the fraction for observation under the optical microscope (particle sizes larger than $0{\cdot}5\mu$) and the submicron fraction is not sampled. This year we began to measure the city air of our capital, Prague, and by these measurements we found a combination of sedimentation and diffusion methods to be most suitable. Further this combination makes it possible to retain the fine and middle aerosol fractions of aerosol by diffusion on fibrous crystals (needles) of copper oxide.

Sampling of Aerosols of Solid Particles and their Appearance

The retention of submicron fraction of aerosol particles

The preparation and application of fibrous microcrystals for aerosol sampling in laboratory work was described by Pfefferkorn.[7, 8] The above mentioned microcrystals vary in width from several tenths to several hundredths of a micron in length to several tens of microns (see Fig. 1).

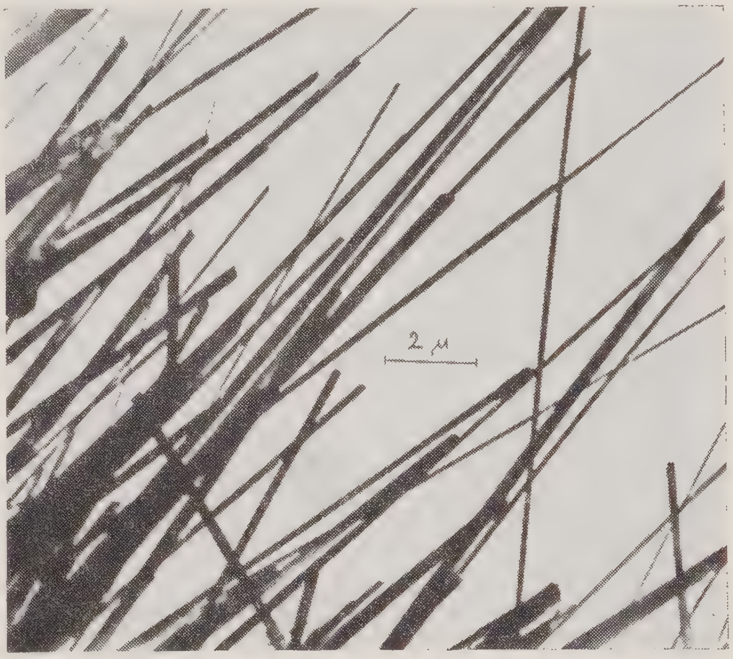

Fig. 1

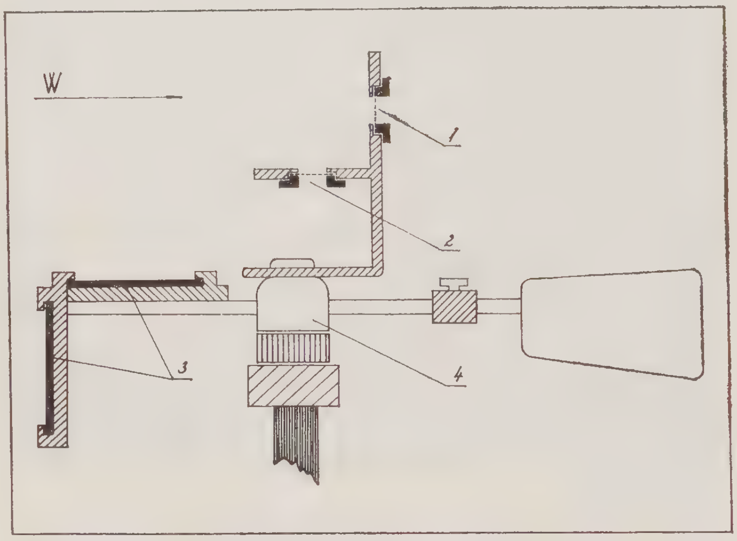

Fig. 2

These oxidation " needles " are prepared by the oxidation of brass or copper wire grid used as the electron microscope specimen grid. Oxidation occurs by a slow flow rate of air passing through a copper grid at 400°C–450°C. The oxidized copper grids serve as the carrying medium for the sampling of solid and liquid aerosol particles. From these wire grids, discs 5 mm in diameter are cut out which are then mounted in special holders (Fig. 2) placed on a weathercock with sedimentation glass-sliders. Polluted atmospheric air passes through the grid by natural flow and the aerosol particles are captured on the needle crystals. Without any further preparations electron micrographs at a magnification 3,000×–4,000× are obtained; and therefore the distribution and the size of the particles, or their chemical composition, could be estimated (e.g. by heating of the grid after the sampling the soot and tar particles could be distinguished from the other mineral dust). The

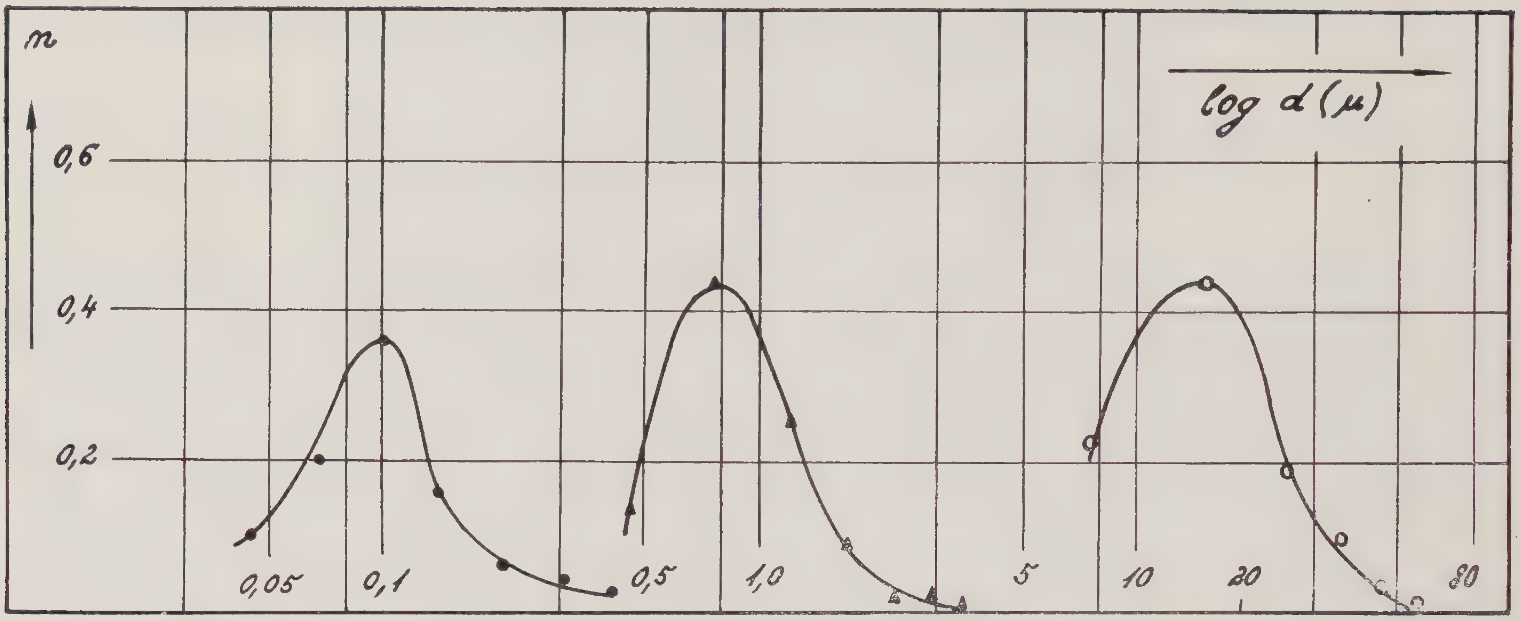

Fig. 3

grids are placed in the middle of the weathercock in horizontal and vertical positions.

Sampling of the coarse aerosol fraction

Large aerosol particles (larger than 1μ) are sampled by sedimentation on perfectly clean microscope slides, covered with a thin vaseline solution (the glass-slides are dipped in 0·5 per cent solution vaseline in xylene). Treated microscope slides are mounted at the end of the weathercock horizontally and vertically (Fig. 2). The size and shape of the aerosol particles is determined (usually after several hours' exposure) by an optical microscope at a magnification 600×–1,000×. The content of the soot and tar droplets may be estimated after heating the slides at the temperature of 400°C–500°C.

The Size and the Nature of the Particles

By measuring the size of the particles (by usual methods[3]) on the electron micrographs and by sedimentation samples on the glass-slides (opitcal microscope) size frequency curves were made. Aerosol samples (made by the described methods) were obtained on several observation stations during the whole year, in various heights at 15, 5, 10 m above the area (Fig. 3).

The results will be summed up statistically for the whole year measurements, but we can certainly estimate the three maximum values in the sizes ranging from 0·05–50μ (0·1μ, 0·8μ, 15·0μ) which correspond to the three types of particles forming the composite city air of Prague (condensation aerosols, ash particles, soot and coagulated ash particles). The shape of the size frequency curve is approaching the logarithmic probability law (Fig. 4).[4, 5]

As to the nature of the aerosol particles sampled by the described method and seen on the figures (Figs. 5, 6) we can estimate that they are of various types. Spherical particles are mainly formed by carbon, or melted inorganic meterial; there are droplets of coal tar, particles of irregular shapes formed either by ash particles (i.e. by insoluble silicates whose colouring under the opitcal microscope is given by trivalent iron) or loose chain aggregates of soot. Besides the described shapes in sedimentation samples aerosol particles of crystal shapes can be found (Fig. 7).

Conclusion

The described method of aerosol sampling from the

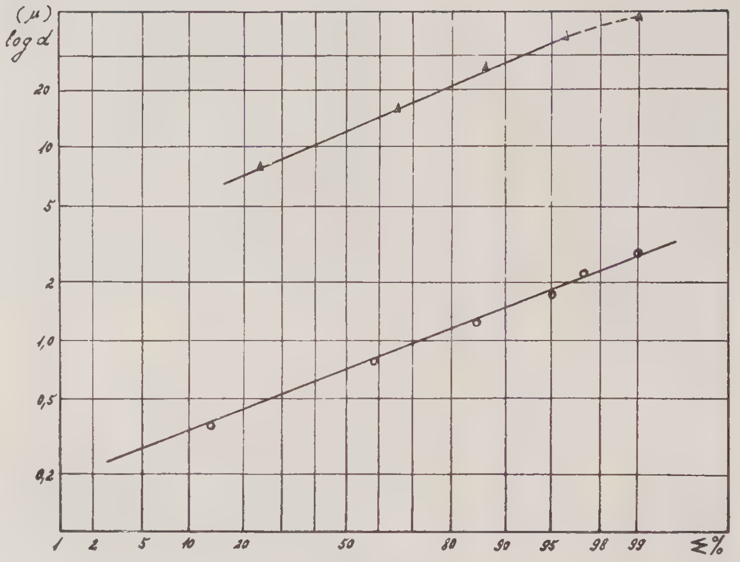

Fig. 4

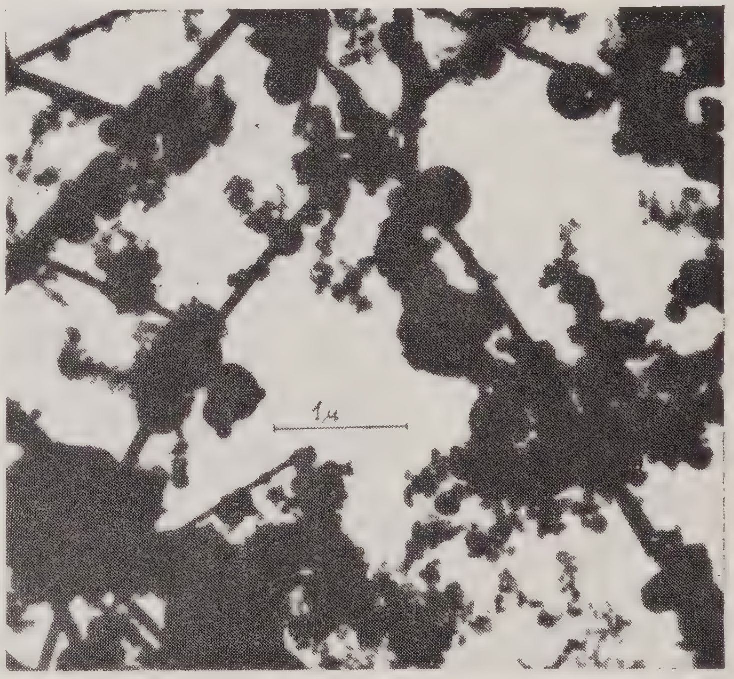

Fig. 5a

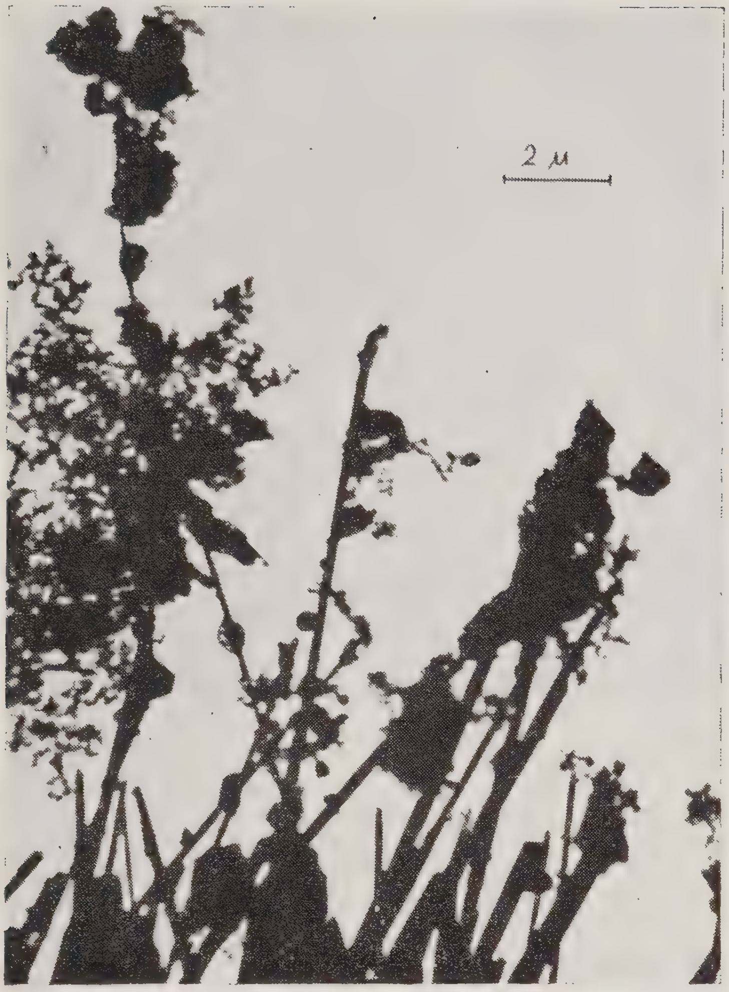

Fig. 5*b*

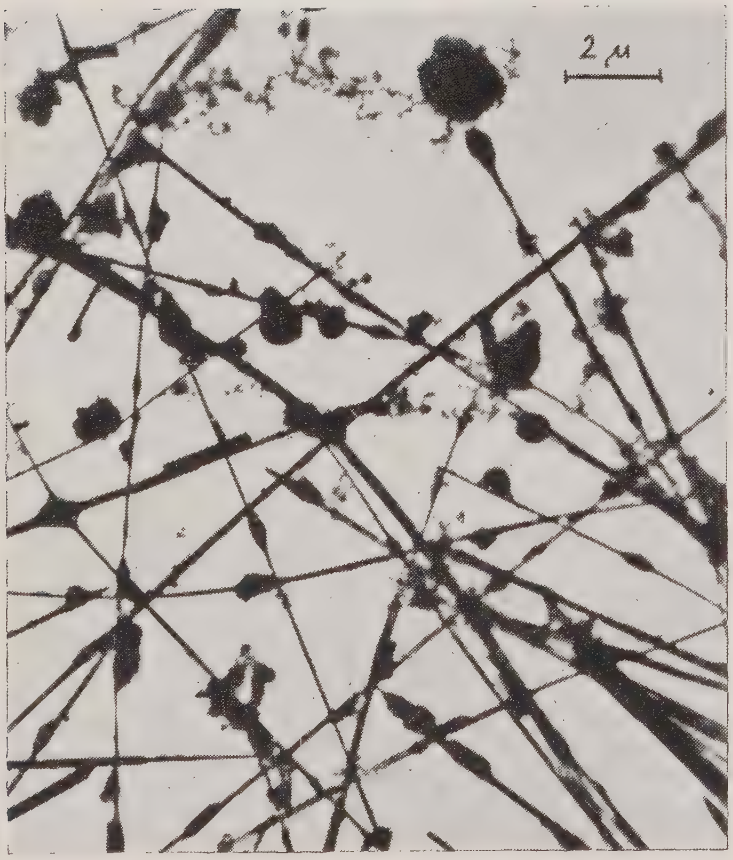

Fig. 5*c*

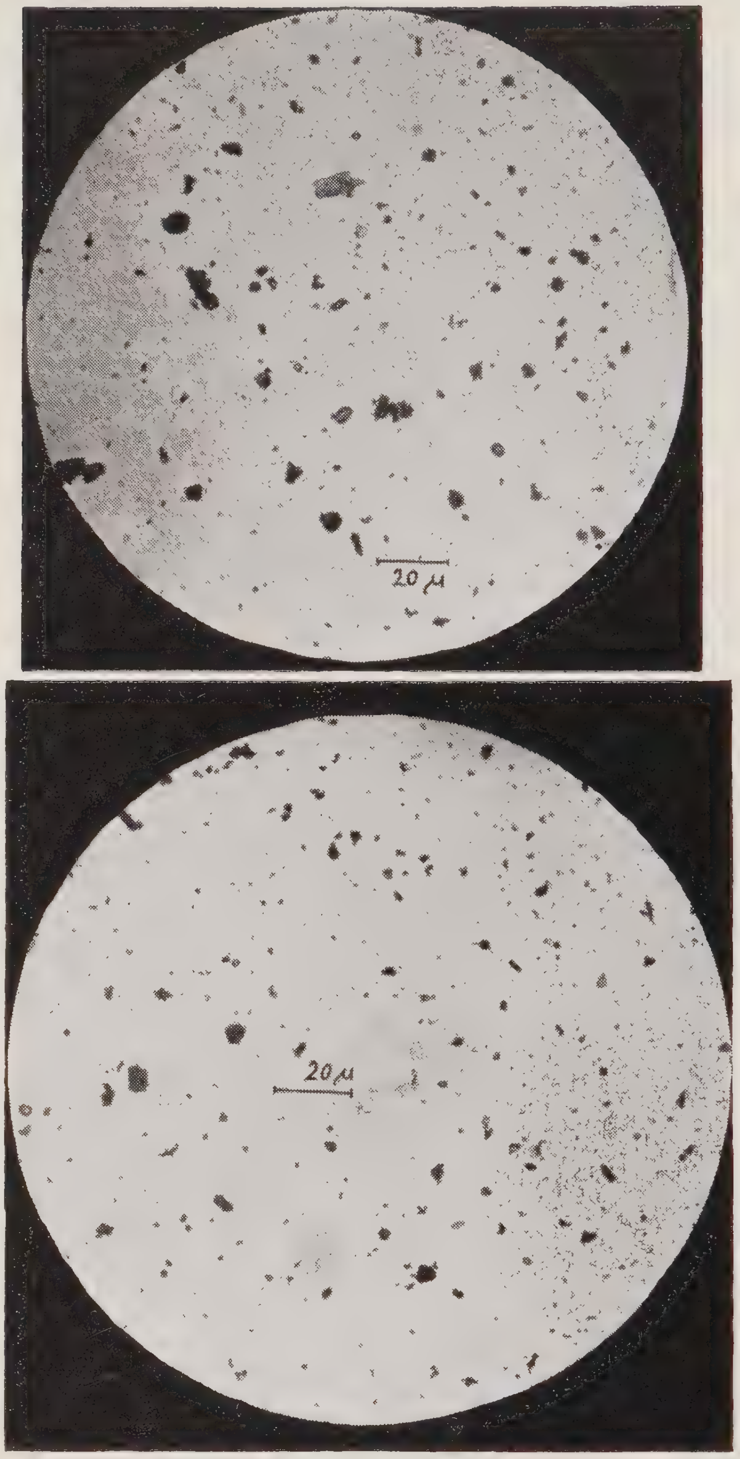

Fig. 6

city air for estimation of sizes and shapes of the particles, based on the combination of the diffusion method on fibrous crystals and the sedimentation method by its simplicity is superior to the thermal or electrostatic precipitator methods. It is sufficient to place in the measured area a weathercock with sedimentation glass slides and with a micro-grid, the exposure time varying from several hours to several days and we obtain suitable samples ready for immediate observation under the optical or the electron microscope (further preparation not being needed). By this method the shape and the approximate chemical composition of the particles can also be determined.

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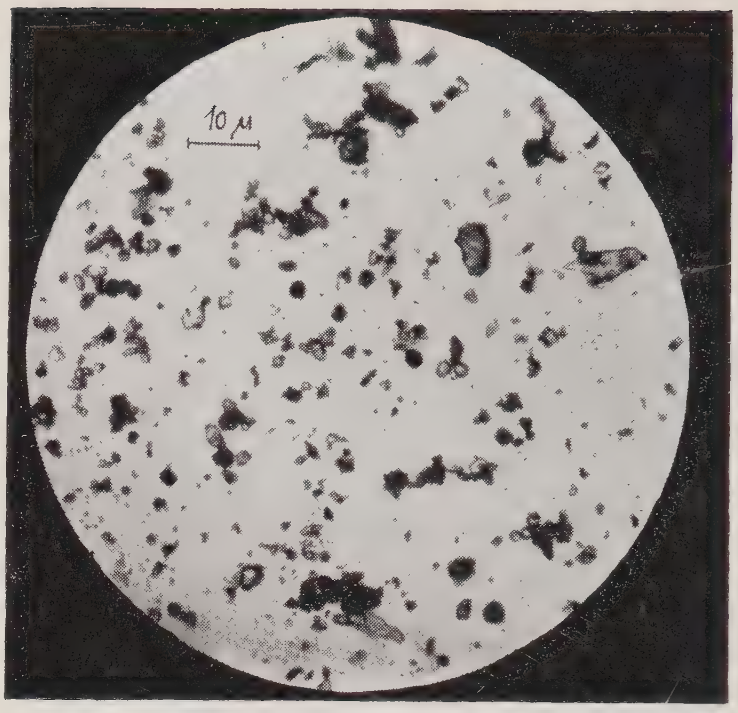

Fig. 7

V. 59

SOME CONCLUSIONS ON THE EXTENT AND POSSIBILITIES OF CO-OPERATIVE RESEARCH IN EUROPE ON AIR CONTAMINANTS

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SUMMARY: The recommendations of the two conferences on air pollution organized by the World Health Organization at Milan and Geneva, are listed. Some international co-operation is already taking place. There is need for further co-operation and exchange of information and as a first step the World Health Organization has prepared a list of organizations and projects now operative in Europe. Other possible steps are to enquire as to individual investigators and investigations; also to arrange visits from consultants to assess further potentialities for co-operation.

Introduction

In drawing up a title for this paper, I was very conscious of the broad character of the subject of air pollution as well as the wide variety of interests involved and I wanted to avoid undertaking a subject which would prove too great to cover adequately. Now, as I am about to present this paper, I find it necessary to mention a very important additional limitation; my discussion must treat the subject primarily from the public health aspect, and in doing so, will consider air pollution in a general sense, not going into the closely related aspects of industrial hygiene or pollution of air in work places, nor into the other animal and plant health or the economic aspects of air pollution.

First International Conference at Milan

One of the first contacts with the World Health Organization with the field of air pollution was in 1957 when the Regional Office for Europe co-sponsored with the Government of Italy a European Conference on the Public Health Aspects of Air Pollution at Milan, November 6–14, 1957. Participants from some 21 countries of Europe assembled there, reported on various aspects of the subject, including a review of replies to questionnaires showing the increasing seriousness of this problem in many European countries and the urgent necessity of adopting control and preventive measures. A report of the conference was published[1] which, among other things, pointed out that a serious handicap in the fight against air pollution is the lack in many instances of demonstrable proof of ill effects on the health of man, animals and plants, and a lack of quantitative information on the specific relationships between air pollutants and ill health.

On this subject, the conference recognized that special studies were required to establish pathological and diagnostic criteria for those diseases which might be related to air pollution. In addition to research on the well-known respiratory diseases and their possible relationship to air pollution, epidemiological research should be encouraged into the general effects of air pollution as well as into the incidence of minor illness and discomfort which may follow air pollution, and into the positive value of fresh air in the maintenance of health.

Another subject which could be proposed for further study was the relationship between infectious, particularly virus, diseases and air pollution.

The conference was of the opinion that there was a need for encouraging engineering research to improve equipment and reduce its cost.

It was strongly recognized that further research should be fostered on the relationship of air pollution and the health of man and animals, as well as on its effects on plant life, but the conference was also satisfied that there was sufficient information available and justification for immediate measures of control.

WHO Expert Committee's Report on Air Pollution

Immediately thereafter, the Expert Committee on Environmental Sanitation of the World Health Organization, at its fifth meeting, Geneva, November 18–23, 1957, discussed the question of air pollution. In the report[2] of this meeting the Committee suggests that a desirable step in the setting-up of air pollution control at the national level is the establishment of an air pollution advisory council which can maintain a supervisory watch on the various aspects of the country's effort. Among other things, this committee sould consider from time to time the results of systematic measurements of air pollution which are being made, advise the government on the research which should be undertaken and on when financial assistance should be given for research work. Thus, the co-operative effort in research would be seen and guided from a national level, from a view of the air pollution problem as a whole and in truest perspective.

Among the specific research needs mentioned by this Committee are the following:

"1. The ability of the atmosphere to disperse concentrations of pollutants varies tremendously. Some of the variations are governed by physical laws which are well known. Intensified research is needed, however, with the object of obtaining more information on the factors affecting air movements in localities of different types, such as the turbulent structure of the wind, and the low-level temperature and wind gradients.

2. On the basis of existing knowledge, much pollution of the atmosphere could be avoided without undue capital expenditure. Certain emissions from special processes, however, appear to be unavoidable with present techniques, and others can be reduced only at great cost. Intensified research is needed to obtain more information on methods of greatly reducing the quantity of pollutants discharged from special processes.

3. Intensified research is needed with the object of obtaining more information on the ultimate interaction and fate of pollutants, especially at times of temperature inversion and fog when the concentration of pollutants is likely to be greatest.

4. The effect of air pollutants on human health is influenced by a number of significant factors, among which may be climate, modes of living and other variables which differ in various parts of the world. Co-operative studies of morbidity and mortality rates need to be made for chronic bronchitis and primary lung cancer in countries for which the different significant variables can be accounted for and standardized.

5. Animal epidemiological investigations of air

pollutants, both in the laboratory and in the field, should be intensified.

6. Additional centres for the laboratory investigation of the toxicity of specific pollutants, groups of pollutants, and grossly polluted ambient air, need to be established.
7. Many air-pollution problems are too complex for immediate and easy solution and therefore require expensive equipment and highly-trained investigators for their resolution. Institutions of higher learning and the appropriate international and governmental agencies should be encouraged to undertake research in solving these more recalcitrant problems.
8. Investigations of the use of indigenous plants or other biological entities as indicators of air pollutants should be intensified."

Not neglected in the report are related subjects of desirable standardization in terminology and in units of measurement, in methods of air analysis and of instruments, so as to permit comparability and accuracy of results as economically as possible.

Also, the collection and dissemination of information is mentioned as necessary as the current status of knowledge is inadequate and ill distributed, and does not permit the establishment of standards of what levels of concentration are safe for man.

Finally, the questions of financing of research, the recruiting, training and mobilization of research workers is touched on.

The distribution of this information has the objective of spreading the knowledge of the types of research now being pursued in this field, of stimulating needed activities and of disclosing possibilities of international co-operative action in this regard.

The next step which is now in preparation is to enquire further as to individual investigations and investigators so engaged. Another possibility is to have competent technical consultants visit some or all of these institutions for the purpose of assessing more closely the possibilities of co-operative research and the specific types and topics which are likely to be necessary and practicable.

With wide distribution of information collected in such ways, it is possible for co-operative research to proceed without further stimulation or other action on the international level.

In a similar way, the World Health Organization is active in the co-ordination of international aspects of sanitary research, for example on drinking water quality and methods of analysis on a global scale and on water pollution in Europe. In the latter instance, it works in collaboration with several other international organizations, notably the Food and Agriculture Organization and the United Nations' Economic Commission for Europe.

At the present time, this is the stage to which the Organization is prepared to act with respect to air pollution research, but further studies of the problem may lead to a decision on the part of this Organization to regard this particular field as worthy as one in which it would undertake further measures " to enhance the international effort to acquire new knowledge for combatting still rampant mass disease ".

Research Mobilization

The question of international co-operative research is not entirely new or unexplored even in the field of air pollution. The assembling of data gathered over large areas is shown to be feasible in such aspects of this field as in meteorology and in the airborne contaminants. In those countries[3] which cover large areas of the globe, networks of stations have been established to detect atmospheric contaminants, not only those resulting from radioactive fallout but also other particulate matter.

For example, a network of some 80 chemical sampling stations[4] now covers all of north-west Europe. This particular scheme originated with the Royal Agricultural College of Sweden and in 1954 an informal international agreement was reached at Stockholm by which the sampling and the study of the chemical composition of air and rain-water is done in a network extending over all Scandinavia, Great Britain, the Netherlands, Belgium and a part of Germany. The data from these networks are published regularly in *Tellus*, a quarterly journal of geophysics in Stockholm.

In a recent document[5] on a study and plan for an intensified WHO medical research programme, the existence of central national research organizations in some 30 countries of the world is pointed out as well as their function to provide guidance and support to the national research effort, without impairing the indispensible freedom of the individual investigator.

However, it is also recognized in this document that there remain research problems which cannot be solved within the national boundaries of any one country. Some air pollution research is of this character. Some of these problems require exploration in particular geographic areas, under varying climatic and meteorological conditions, among populations of varying or particular conditions of living, and with varying industries or other sources. Thus, co-ordinated and co-operative research in differing parts of the world to yield comparable results, international teamwork to pool talent, and better exchange of knowledge to expedite scientific progress are essential if gaps in knowledge are to be filled. For this, initiation by such international organizations as the World Health Organization is increasingly recognized as one of their proper functions.

In an approach to this, the European Office of the World Health Organization, in accordance with a basic principle of WHO's work to operate through existing national organizations, has requested and has secured from a number of governments of its Member States information on the investigators and investigations now being carried on in European countries in both fundamental and applied research on the public health aspects of air pollution and its control. The organizations and institutions which have been reported as carrying on such studies are listed in the Annex to this paper*.

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*List of Organisations and Institutions in Europe reported to be interested or active in research on the public health aspects of air pollution, classified according to country, based on a questionnaire addressed to all governments of Member States of the European Region of the World Health Organisation dated May 6, 1959.

V. 60

THE EMISSION OF OXIDES OF SULPHUR FROM DOMESTIC APPLIANCES.

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SUMMARY: The paper deals with the effect on sulphur dioxide emission of using gas and coke in place of other fuels, particularly bituminous coal. The emission of sulphur from different fuels are compared. Coke fires, owing to greater efficiency, give off less sulphur dioxide than coal fires. Improvements in gas appliances and tariffs are making gas heating a more attractive proposition. Use of gas reduces sulphur dioxide emission a hundred times. Further reductions are expected from gas which is even more sulphur free.

The overriding significance of atmospheric pollution from the domestic open coal fire has been discussed many times; also the total emission of oxides of sulphur to the atmosphere from all fuels. This note is limited to the effect on sulphur oxide emission of using gas and coke for domestic purposes in place of other fuels, particularly bituminous coal. Although reference is only made to the relative proportions of oxides of sulphur produced by the combustion of coal, coke and gas, it is essential to remember that this is only one aspect of air pollution. Any oxides of sulphur are much more deleterious to human health and more active in corrosion of materials when associated with solid particles such as smoke or ash. These solid particles not only provide a harmful vehicle but it seems likely that they aid the oxidation of sulphur dioxide to sulphur trioxide and it is the sulphur troxide which is particularly active.

A first approach is to consider the gross sulphur content of different fuels, expressed on a common basis of grains of sulphur per gross therm. Then, the practical efficiency of utilization must be taken into account in order to obtain a comparative figure of the emission of oxides of sulphur if an open coal fire were replaced by coke or by gas providing an equivalent heat service.

Table I is a summary of information available of the sulphur content of the various fuels expressed in grains of sulphur per gross therm.

It will be noted that the sulphur content of coke is very similar to that of coal, from which it was produced, and the value for gas is about one-thirtieth on this gross basis.

In smoke control areas, the major contribution to the reduction of air pollution will be the replacement of the open coal fire or the open coal fire with back boiler or the kitchen range by a coke burning appliance or by a gas fire, gas water heater and gas cooker as required to give equivalent service. If the open coal fire in the living room is replaced by a gas fire it should be of the high efficiency convector type, as a high efficiency fire is necessary for gas to compete in running cost with an open solid fuel fire.

Coke is the most readily available solid smokeless fuel in quantity at a price advantageous to the user, for a given heat service, compared with coal.

Improvements in gas appliance efficiency, changes in gas prices in relation to solid fuel and above all new gas tariffs have however more and more made a convector gas fire economically attractive for living-room heating. Such appliances are higher in capital cost than open coke fires but must be considered seriously as a long-term heating policy.

As far as fuel oil and kerosene are concerned, a different type of heating from the open fire is introduced, but the comparison with gas either for flueless heating with kerosene or for central heating or for warm air heating can reasonably be considered on the basis of the gross sulphur content of the fuel already quoted.

The most important practical case is the comparison of like with like when the radiant fire is being considered.

Comparisons of practical efficiencies are difficult to assess with accuracy as it is not sufficient to compare the bench efficiency of one appliance with another. On the one hand gas shows a substantial gain in practical efficiency compared with solid fuel not only on the basis of a higher thermal efficiency but also owing to its greater flexibility under the intermittent conditions of heating obtaining in this country; on the other hand, a high efficiency appliance must be used for gas with a satisfactory tariff or the standard of heating obtained in practice might be affected by economic considerations. The following figures are taken as the best estimates available from bench thermal efficiencies and field trials, both inside the industry and by outside authorities. It is assumed that the ventilation rate in a living-room with an open coal fire will be something like 7,500 cu ft/hr, or 4,000 cu ft/hr from a convector open fire with restricted

Table I

Fuel	*Per cent S by weight*		*Grains S/ therm*	*Per cent S emitted as oxides*
	Spread	*Average*		
Coal	1–2[1] 0·5–4[6]	1·5[1, 3, 5]	850	80[3]
Coke	1–2[1, 3]	1·5	900[7]	80[3]
Anthracite	—	1[3]	450[4]	80[3]
Town Gas	0·038–0·075	0·056	30	100
Fuel Oil (Heavy) ...	2–4[2]	3	1,100[4]	100
Diesel Oil	—	0·9[4]	300[4]	100
Kerosene	0·04–0·08[4]	0·06	21[4]	100

flue, or 3,000 cu ft/hr from a high efficiency convector gas fire with controlled ventilation. Table II gives the fuel equivalent used in terms of 1 ton of coal on an open coal fire for a similar heat service in practice for the main living-room heating of a house.

Taking these figures for the practical equivalent in use, the following Table III compares the emission of oxides of sulphur. In the Table an average figure is taken for coal and coke of 850 grains of sulphur per therm, and for gas 30 grains per therm.

It has been assumed so far that all the sulphur in all the fuels is converted to sulphur dioxide on combustion, whereas some is burnt directly to sulphur trioxide. It has not, however, been possible to find reliable evidence of this proportion although sulphur dioxide undoubtedly predominates very largely, figures quoted are as high as 60/1. It may well be that further work on this aspect is desirable as preliminary work has shown that the proportion of sulphur trioxide can be affected by the design of the combustion chamber and the control of air to it.

Coke does not give smoke and does give some reduction in oxides of sulphur compared with coal due to higher utilization efficiency. The sulphur content from the combustion of town gas at the moment is so small that any changeover to gas would be a major contribution to sulphur reduction in the atmosphere; e.g. about 80 gas fires give the same total output of oxides of sulphur as one open coal fire. Such a changeover from solid fuel to gas for the main domestic heating services is in line with recent developments in gas manufacture and appliance design.

It should also be noted that the sulphur content of town gas has been progressively reduced over the years, and it is the intention to bring this value down to well under 15 grains per therm, i.e. half the present average value. This reduction in sulphur content is not being done in the interests of atmospheric pollution but in order to simplify the design and maintenance of gas appliances. It is also important that the tendency of future gas supply is to increase the proportion of gas in relation to coke, and also to introduce gas making processes, e.g. from refinery gas and from methane, which not only produce a virtually sulphur-free gas but avoid any appreciable emission of oxides of sulphur on the gas works.

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Table II

Fuel	*Appliance*	*Quantity of Fuel Equivalent to 1 ton of Coal*	*Gross Therms*
Coal	Stool bottom grate	20 cwts	280
Coal	Convector open fire	14 cwts	200
Coke	Approved open fire	15 cwts	200
Coke	Convector open fire	11 cwts	150
Gas	High efficiency convector fire	85 therms	85

Table III

Appliance	*Similar Service* *Ratio of production of oxides of sulphur*
Open coal fire	77
Convector open coal fire	54
Coke open fire	59
Coke convector open fire	42
Gas—high efficiency convector fire	1

MORBIDITY AND MORTALITY FROM BRONCHITIS IN SHEFFIELD IN FOUR PERIODS OF SEVERE AIR POLLUTION

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SUMMARY: Bronchitis sickness certificates were used as a source of information on morbidity from bronchitis. They showed rapid and consistent increases during periods of increased air pollution. Bronchitis deaths are less satisfactory as an index of the effect of a smog on health. The sickness certificates have shown their value as a research tool.

In October 1956 the Medical Research Council set up a Research Group at Sheffield University under the direction of Dr. (now Professor) John Pemberton to study respiratory disease in Sheffield in relation to air pollution.

Information about morbidity from respiratory disease was obtained from sickness certificates by courtesy of the Ministry of Pensions and National Insurance and the managers of their local offices. Certain information about sickness certificates relating to bronchitis was given without infringing the confidential nature of these documents. This source of information about respiratory morbidity, by means of which day-to-day changes in the numbers of "first certificates" for bronchitis could be related to changes in air pollution and in the weather, had not hitherto been used. Death certificates in which bronchitis was given as the underlying cause were also analysed so that a similar comparison could be made.

Air pollution readings for this study were obtained from a single sampling instrument in the city centre which, unlike most of the other twenty-nine instruments in use, is changed daily, including Sundays. It is one of eight operated by the local authority and is the standard volumetric type recommended by the Department of Scientific and Industrial Research, using 2 in. filters. The values given are those for the 24 hours from 10 a.m. on the date stated.

The figures for temperature used here are those for the minimum temperature in the 24 hours from 9 a.m. on the date stated, and were provided by the city's weather office at Weston Park, about half a mile from the city centre.

In the analysis of the bronchitis sickness certificates, it was considered that prolonged illness was more likely to occur in persons already susceptible by reason of chronic bronchitis, and therefore a separate analysis was made of those lasting less than three weeks, which would probably represent the experience of the healthier section of the community. These shorter illnesses have been used in this paper. The complete figures will be published later.

Owing to a marked weekly cycle in the numbers of these certificates, which are numerous on Mondays because they are hardly ever issued on Sundays, and much fewer on Thursdays and Fridays, comparison of the crude figures gives no clear indication of any real changes from one day to the next. If, however, the basic weekly pattern is established, the actual number on any one day can be compared with the average for that day and the resulting ratios will give a more accurate picture of day-to-day changes. The longest continuous period for which data from these certificates was available was seventy weeks, covering two winters and the intervening summer. The average number of "first certificates" for each day of the week for this period was calculated. These are the "expected numbers" quoted in the tables. They do not take into account the seasonal variations about this average, nor the differences which occur between one winter and the next.

This paper is concerned chiefly with the four typical, severe "smog" episodes which occurred during the period studied (November 1956 to January 1959 inclusive). As far as the less severe peaks of pollution were concerned, it can be stated that after allowing for seasonal differences in the general level of sickness the majority were associated with an increase in bronchitis sickness certificates and some with an increase in deaths from bronchitis. In Tables I to IV results are given for each of the four "smog" periods. Since deaths from bronchitis were very few, a five-day moving average was calculated to smooth out random variations. Figs. 1 and 2 illustrate the results given in the tables.

In every case the rise in smoke concentration was proportionately greater than the rise in sulphur dioxide. The temperature fell to below freezing point during each smog; but low temperatures without increased pollution were never accompanied by large increases in morbidity or mortality from bronchitis.

Bronchitis sickness certificates were found to increase in numbers for a few days immediately after the Christmas holiday each year, by an amount which almost exactly compensated for the decreased numbers sent in during the previous three weeks. Apart from these few days each year, bronchitis sickness certificates never rose to the levels reached during the four smog periods. In each of these the ratio rose to more than twice the expected number, a sharp rise occurring on the day after the onset of the smog in two cases and on the next day in the other two. A further sharp rise followed, even in the November 1956 period when pollution had returned to normal by the third day. In January 1959 a day intervened before the second rise, probably because the level of pollution fell after the first day and then rose again to a peak on the fourth day. There was a rapid return to normal numbers of certificates when the smog periods ended.

In all but the first smog the 5-day averages of bronchitis deaths increased in very much the same way as the sickness certificates, though they remained up a little longer. In November 1956 the smog was preceded by a sharp increase in bronchitis deaths and in this case there was a fall in the number of deaths during the fog.

Bronchitis sickness certificates, used as an index of morbidity from bronchitis in the general population, showed rapid and consistent increases during periods of increased air pollution. It will be possible to determine the actual numbers of working days lost on each occasion and to compare this with other causes of sickness absence. Bronchitis deaths are less satisfactory as an index of the effect of a smog on health because there are so few of them in one day in any one city; also they rise to similar levels on occasions when there is no pollution. The sickness certificates have shown their value as a research tool and it is hoped that they may be used to good effect in other studies.

Table I

Air Pollution, Temperature and Bronchitis Morbidity and Mortality in Sheffield from 16th-24th November, 1956

Day	*F*	*S*	S	*M*	*T*	*W*	*T*	*F*	*S*
Date: November 1956	16	17	18	19	20	21	22	23	24
Smoke (city centre) mg./100 cu. m. ...	27	40	40	18	17	115	161	51	9
SO_2 (city centre) p.p. 100 million ...	18	24	24	25	15	40	45	28	18
Minimum Temperature °F.	42	43	40	39	38	27	30	35	39
Bronchitis Sickness Certificates (Duration under 3 weeks)									
No. of onsets per day	15	16	—	44	27	19	25	33	26
Expected number (average over 70 wks.)	12	17	—	37	20	16	13	12	17
Ratio of observed/expected numbers ...	1·3	1·0	—	1·2	1·4	1·2	1·9	2·8	1·5
Bronchitis Deaths									
Actual numbers	4	—	2	3	2	—	1	1	—
5-day moving average	1·4	1·8	2·2	1·4	1·6	1·4	0·8	0·6	1·0

Table II

Air Pollution, Temperature and Bronchitis Morbidity and Mortality in Sheffield from 14th-24th December, 1956

Day	*F*	*S*	S	*M*	*T*	*W*	*T*	*F*	*S*	S	*M*
Date: December 1956	14	15	16	17	18	19	20	21	22	23	24
Smoke (city centre) mg./100 cu. m.	10	10	16	18	38	107	125	163	101	15	16
SO_2 (city centre) p.p. 100 million	22	19	15	21	27	39	41	48	29	22	20
Minimum Temperature °F	42	43	40	39	35	34	25	25	35	33	30
Bronchitis Sickness Certificates (duration under 3 weeks)											
No. of onsets per day ...	6	11	—	20	12	12	17	32	22	—	28
Expected number (average over 70 weeks)	12	17	—	37	20	16	13	12	17	—	37
Ratio of observed/expected number	0·5	0·7	—	0·5	0·6	0·7	1·3	2·7	1·3	—	0·8
Bronchitis Deaths											
Actual numbers... ...	—	—	2	—	1	2	1	3	4	2	3
5-day moving average ...	1·2	0·8	0·6	1·0	1·2	1·4	1·8	2·4	2·6	2·6	2·4

Table III

Air Pollution, Temperature and Bronchitis Morbidity and Mortality in Sheffield from 21st-29th November, 1958

Day	*F*	*S*	S	*M*	*T*	*W*	*T*	*F*	*S*
Date: November 1958	21	22	23	24	25	26	27	28	29
Smoke (city centre) mg./100 cu. m. ...	22	6	48	64	155	230	117	114	35
SO_2 (city centre) p.p. 100 million ...	19	9	23	25	62	72	58	56	18
Minimum Temperature °F.	41	41	40	48	31	32	37	32	32
BRONCHITIS SICKNESS CERTIFICATES (duration under 3 weeks)									
No. of onsets per day	9	10	—	49	27	26	31	33	25
Expected number (average over 70 wks.)	12	17	—	37	20	16	13	12	17
Ratio of observed/expected numbers ...	0·8	0·6	—	1·3	1·4	1·6	2·4	2·9	1·5
BRONCHITIS DEATHS									
Actual numbers	2	—	1	—	—	2	2	1	5
5-day moving average	1·2	1·0	0·6	0·6	1·0	1·0	2·0	2·6	2·2

Table IV

Air Pollution, Temperature and Bronchitis Morbidity and Mortality in Sheffield from 24th-31st January, 1959

Day	*S*	S	*M*	*T*	*W*	*T*	*F*	*S*
Date: January 1959	24	25	26	27	28	29	30	31
Smoke (city centre) mg./100 cu. m.	58	122	61	95	159	145	27	39
SO_2 (city centre) p.p. 100 million...	40	28	28	35	62	54	18	18
Minimum Temperature °F.	29	26	29	30	32	39	36	35
BRONCHITIS SICKNESS CERTIFICATES (duration under 3 weeks)								
No. of onsets per day	17	—	37	29	24	29	26	28
Expected number (average over 70 weeks) ...	17	—	37	20	16	13	12	17
Ratio of observed/expected numbers	1·0	—	1·0	1·5	1·5	2·2	2·2	1·7
BRONCHITIS DEATHS								
Actual numbers	1	2	—	1	3	2	3	1
5-day moving average	1·2	0·8	1·2	1·2	1·8	1·8	1·8	1·8

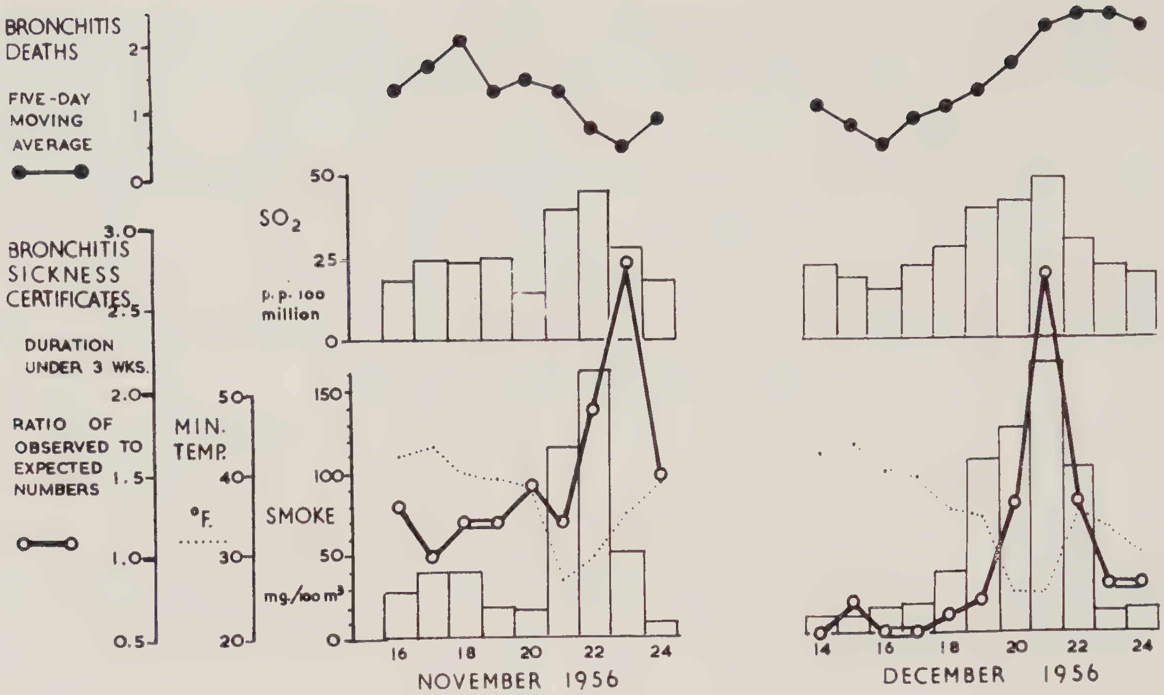

Fig. 1. *Air pollution, temperature and bronchitis morbidity and mortality in Sheffield during "smog" periods in November and December* 1956. *The upper and lower histograms represent respectively sulphur dioxide and smoke values at the city centre, and minimum temperatures are shown by a dotted line. Solid circles show deaths from bronchitis as a* 5-*day moving average and open circles the ratio of observed to expected numbers of bronchitis sickness certificates for a given day. Since no certificates are issued on Sundays these have been given the same value as the Monday following and the two days have been linked by a double line.*

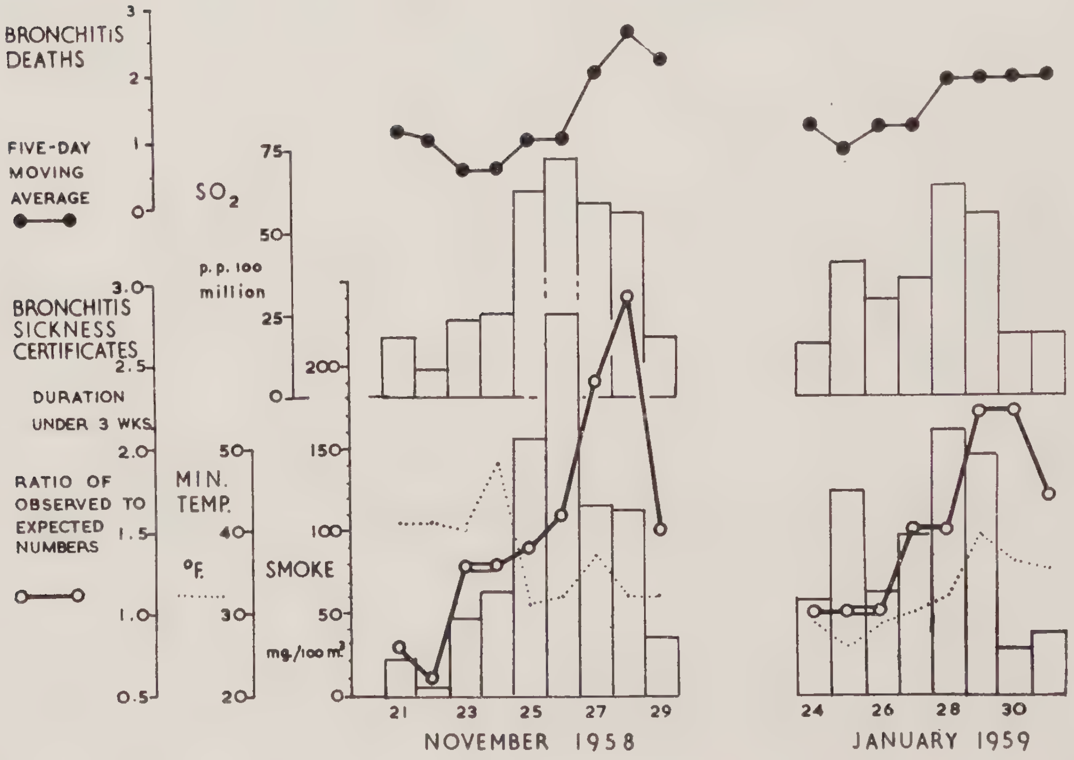

Fig. 2. *Air pollution, temperature and bronchitis morbidity and mortality in Sheffield during "smog" periods in November* 1958 *and January* 1959. (*All symbols as in Fig.* 1.)

RESEARCH ON DAMAGE TO VEGETATION FROM AIR POLLUTION AT THE UNIVERSITY OF CALIFORNIA, RIVERSIDE

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SUMMARY: The research is directed to the study of air pollution effects on agricultural crops, methods of reducing plant damage, and identification of phytotoxicants. The instrumentation used and the pollutants being studied are listed. Experiments are designed to determine the range of plants injured; symptoms of such injury and the time concentration levels required; effects on plant growth of both lethal and sub-lethal; the nature of toxic action and identification of the phytotoxicants where these are not known.

Research in air pollution at the University of California Citrus Experiment Station at Riverside is directed to the study of its effect on agricultural crops, methods of reducing plant damage and identification of phytotoxicants. The relation of plant damage to eye irritation from certain pollutants is also being studied. Investigations are organized under an interdepartmental Air Pollution Research Committee with staff from the four departments of Horticulture, Plant Biochemistry, Plant Pathology, and Soils and Plant Nutrition participating. The work of these researchers is co-ordinated with that of the Agricultural Extension Service who conduct a statewide survey to determine the location, nature, and extent of plant damage.

The programme is supported in the main by University budget appropriations and, in part, by grants and gifts from growers, local and federal agencies, and certain industrial groups.

Staff of William E. Scott and Associates, Perkasie, Pa., under contract with the American Petroleum Institute, are also co-operating at Riverside with special emphasis on a study of the chemical reactions in polluted atmospheres to determine the identity of as yet unknown phototoxicants and eye irritants.

Facilities for investigation include two glasshouses for growing of experimental plant material and 15 glass walled (using natural light) or solid walled (using artificial light) fumigation spaces varying in volume from 16 cubic feet to approximately 3,000 cubic feet. These facilities are air conditioned and the air they receive is filtered through activated carbon to remove pollutants. Fumigations are conducted under dynamic air flow systems, the fumigants being added in known volumes to the clean air supply.

Special instrumentation used are long path infra-red spectroscopy, conventional and time-of-flight mass spectroscopy, nuclear magnetic resonance and electron paramagnetic resonance spectroscopy, gas chromatography, and automatic recorders for oxidants, ozone, oxides of nitrogen, sulphur dioxide, and carbon monoxide.

The pollutants being studied are gaseous in nature and include oxidants, oxone, fluorides, ethylene and other low molecular weight hydrocarbons, and sulphur dioxide. These are the most important phytotoxic pollutants in California as determined by extensive research on identification and characterization of the phytotoxicants on a variety of plants both in controlled fumigation experiments and in the field, coupled with air measurements made by county and state agencies.

Experiments with the above materials are designed to determine the range of plants injured; symptoms of such injury and the time-concentration levels required; effects on plant growth of both lethal and sub-lethal concentrations; the nature of toxic action as shown by changes in tissues and cell physiology, enxyme systems, and related studies; and to identify the phytotoxicants where these are not known.

The term oxidants is applied to those toxicants, as yet unidentified, produced from the photochemical reactions of oxides of nitrogen and organic materials, principally hydrocarbons. Relatively strong oxidizing ability is a common chemical property. Ozone is also a product of these reactions, but because it is identifiable, does not irritate eyes while oxidants do, and some of its effects on plants differ from the effects of oxidants, it is not included in the class of oxidants. The latter term is reserved, for the moment, for those phytotoxicants that have not been identified. Oxidants and ozone are not related to specific sources. Their formation depends on emissions from a multitude of combustion processes, the principal one being auto exhaust.

Oxidants cause characteristic bronze or silver markings to the under leaf surface of many vegetable crops. Ozone causes a flecking, stippling, or bleaching of the upper leaf surface of many plants and can be distinguished from oxidant damage. Other harnful effects from both pollutants include suppression of plant growth, leaf abscission, reductions in rate of water uptake and photosynthetic activity, and increases in respiration rate and cell wall permeability.

Oxidant and ozone damage can be prevented experimentally with dithiocarbamates and other antioxidizing materials applied as dusts to the foliage and by vitamin C applied as foliage sprays or included in nutrient solutions. Protection from the former treatment is localized and is obtained only when dusts are applied to the lower leaf surface, while that obtained from vitamin C treatment is systemic.

Oxidants have long been characteristic of air pollution in the Los Angeles area. Surveys reveal, however, that oxidant-type plant damage is no longer confined to southern California, but is now found in the San Francisco Bay Region and in the great Central Valley.

Damage from fluorides is related to specific industrial sources of air pollution. Tan to brown necrotic leaf margins are typical of injury to several plants. Studies on citrus have shown that exposure to hydrogen fluoride gas at a few parts per billion for several months suppresses growth, stimulates leaf fall, reduces leaf size, and may cause chlorotic leaf marking.

Ethylene is believed to be responsible for injury to flowers of orchids, roses, carnations and snapdragons in glass-houses in the Los Angeles and San Francisco Bay areas. This gas is present in auto exhausts and may come, also, from the combustion of other organic fuels. Other low molecular weight hydrocarbons from combustion processes are also being studied for their effects on plants.

Sulphur dioxide, perhaps the best known of airborne phytotoxic agents, is not a problem to those industrial areas of California where adequate control devices have been installed. Citrus has been found to be very resistant to this gas. The reaction of several grape varieties is being studied.

AN ELECTRO-PRECIPITATOR FOR THE ASSESSMENT OF DOMESTIC SMOKE

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SUMMARY: The disadvantages of various traditional methods of measuring the smoke emission from domestic appliances are discussed. It is suggested that a more reliable measurement may be made by removing and directly weighing the whole of the smoke in the flue gases, and a suitably designed electro-precipitator is selected as the best instrument for this purpose.

The factors affecting the design of such an instrument are discussed. There follows a description of the finished instrument, which is a single-stage, multi-tube precipitator of height 23 in., overall diameter 13 in., and weight approximately 15 lb. It is capable of collecting all the smoke emitted from a charge of coal on a domestic appliance under normal operation.

Introduction

Since the passing of the Clean Air Act, the accurate measurement of domestic smoke emission has become necessary in order that standards may be set in authorized fuels and appliances for Smoke Control Areas. Although such properties as the toxicity and particle size distribution of the smoke particles play an important part in atmospheric pollution, the overriding factor is the actual weight of smoke discharged into the atmosphere. The authors, working in the Domestic Appliance Laboratories of the British Coal Utilization Research Association, have therefore concentrated their attention upon apparatus which enables domestic smoke emission to be assessed in gravimetric terms.

In the past, reliance has been placed upon the use of inferential techniques for this purpose. It has either been assumed that the concentration of the smoke was proportional to its optical density, or that an assessment of the total weight of smoke could be obtained by withdrawing a relatively small sample of the flue gases, and measuring the weight of smoke contained therein.

Neither of these methods is very reliable, however. The authors have recently shown that the ratio between optical density and concentration is far from constant for domestic smokes.[1] Doubts must also be expressed regarding sampling technique, for a number of reasons. The smoke emission from a domestic fire is too unsteady and of too short a duration after each refuel to be measured either by traversing the flue with a sampling probe or by selecting a single position in the chimney which will yield a representative sample. The probe itself may disturb the pattern of flow in the relatively narrow duct of the domestic chimney, introducing further errors. Moreover, both optical and sampling methods require continuous records of flue gas volume flow and temperature—measurements which are extremely difficult to make accurately with smoke-laden gases.

It is clear that any method which would enable the smoke to be removed from the whole of the flue gases and its weight to be determined directly would eliminate the various difficulties encountered with the inferential methods discussed above. It was for this reason that the instrument described in this paper was developed.

Design Considerations

In electro-precipitation, the smoke particles passing through the instrument are charged by electrons generated in a corona discharge. Once charged, they move towards an earthed electrode under the action of a potential gradient. Charging and precipitation may take place either in two separate zones or in a single stage, in which case the electric field which causes the corona discharge is also used to effect the precipitation. This latter system, consisting essentially of an earthed tube or plates enclosing an elongated electrode maintained at a high potential, seemed more suitable for the present purpose, where simplicity of operation is a prime consideration.

It has been shown[2 3 4] that the number of particles precipitated (and hence efficiency) increases as an exponential function of the length of the tube and decreases similarly with increase in the velocity of the particles along the tube. Efficiency is also a function of the difference between operating voltage and corona starting voltage. Thus, if either a wire or a rod is used, the diameter should be as small as possible to establish a corona at the lowest possible voltage.

The nature of particles to be precipitated has an important though rather more complicated effect on efficiency. Particles of conducting material are more easily precipitated than non-conductors and large particles more readily than small. The dielectric properties also affect the behaviour of the particles after precipitation. Those which are conducting give up their charge on reaching the earthed surface, and are then retained by molecular forces. Non-conductors tend to remain charged and are thus in addition retained by electrical forces.

In domestic smokes, particles with a wide range of conductivities are encountered. The distillation products emitted during the early stages of combustion of bituminous coals are insulators, but as combustion proceeds the particles become more conducting, culminating, towards the end of the emission, in particles of high carbon content, which are for the most part highly conducting. This cycle is one which greatly simplifies the problems of preventing re-entrainment, as the tars provide a tacky base upon which the conducting particles are held with considerable mechanical force.

Although many small precipitators have been designed for experimental purpose, the main applications have been in the air conditioning and industrial fields, where robustness and long life, combined with a reasonably high efficiency, are of main importance. In designing the instrument now under consideration, other factors predominated. The first was that the instrument should maintain a very high efficiency over a wide range of conditions. In addition to having the best electrical design for high efficiency, it was necessary to ensure that the collecting surface should be large enough to hold all the smoke deposit. It was also essential that the complete instrument should be light enough for changes in the weight of between one and two ounces to be measured with an accuracy of 2–4%. In addition the instrument had to be as robust as possible, convenient to handle and easily cleaned.

Preliminary Investigations

Although the theoretical factors outlined in the previous section gave some general guidance, uncertainty about the dielectric properties and size distribution of the smoke particles made it necessary to conduct a series of practical investigations before the final instrument could be constructed.

Basic Arrangement

First, various arrangements of electrodes and earthed surfaces were investigated. From these investigations, it quickly became apparent that the only arrangement which would provide sufficient surface area was a nest of tubes, each having an electrode in the form of a wire along its vertical axis.

Electrodes

Theory suggests that the charged electrode should be of such dimensions as to promote corona discharge at the lowest possible voltage. This can be achieved either by using an electrode having sharp edges or alternatively, if a plain wire or rod is used, by one having the smallest practicable diameter. A series of investigations in which samples of flue gases were drawn through single-tube precipitators confirmed that the wire forming the charged electrode had an important bearing upon efficiency. Various forms of electrodes were investigated, including wire spirals and twisted strip. It soon became apparent, however, that the most practical arrangement was a fine wire stretched along the axis of the tube. Experiments confirmed that the smaller the wire diameter, the more easily was precipitation effected. However, the mechanical strength of the wire, which had to be maintained under tension to prevent excessive vibration, limited the diameter to approximately ·006 in. To resist elongation, wire of fairly high tensile strength was necessary, and since ordinary steel wire was found to corrode rapidly, hard drawn stainless steel wire was used.

Tube Dimension

So far as efficiency of precipitation is concerned, tube diameter is relatively unimportant, provided that the operating potential can be increased to compensate for increases in diameter. Generally speaking, however, the length of insulator is roughly proportional to the maximum potential to be used and if large tube diameters are employed, it is at the expense of the increased weight due to larger insulators. Moreover, for any given overall cross section, the greater the number of tubes, the greater is the area available to receive deposit. Thus, to keep the weight and sizes of the insulators to a minimum and to provide a reasonable collecting area, a design based upon a tube diameter of 1·0–1·25 in. was chosen.

Insulators

Various materials were investigated before a suitable insulator was found. Commercially available insulators of the usual glazed ceramic material were too bulky to be used. Insulators were therefore made from several types of reinforced plastic. These were found to be quite satisfactory until breakdown due to tracking occurred. After this, there was always a tendency for breakdown to occur again along the track made by the previous spark. However, a proprietary insulation material made from glass and mica was found which did not suffer from this defect. After tracking had occurred on this insulator, cleaning with a suitable solvent completely restored its normal properties.

The Complete Instrument. Electro-precipitator with Hexagonal Tubes

The best design of an instrument consisting of a nest of parallel tubes is obtained when the tubes are hexagonal in cross section. This enables them to be fitted together in a honeycombed formation, and makes it possible for the free area of the instrument to approximate to the overall cross sectional area, thus ensuring the least disturbance to the flow of gases. In addition, the close packing possible with hexagonal tubes gives a larger overall collecting area than that obtained with an instrument of the same external dimensions having tubes of circular cross section.

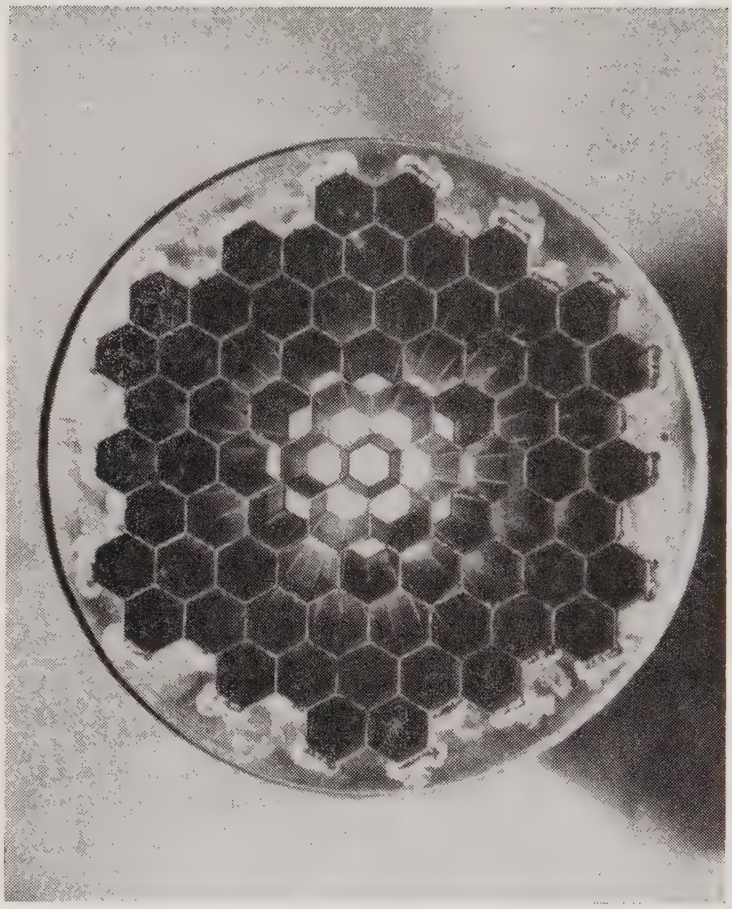

Fig. 1

Using hexagonal tube of 22 s.w.g. aluminium alloy having an external size of 1·2 in. across flats, it is possible to form a honeycomb consisting of 73 tubes with a circumscribing diameter of 13 in., as illustrated by the plan view of the tube assembly in Fig. 1. By utilizing the outside of some of the tubes as collecting surfaces, this assembly can be made up from 54 individual tubes. Where a tube is formed by the outside of six adjacent tubes, a 0·5 in. long spacer is inserted at each end to preserve the rigidity of the complete assembly. The ends of the tubes are Argon-arc welded together, and the tube assembly is welded to flanged circular end-plates of 18 s.w.g. aluminium.

Fig. 2 is a photograph of the complete precipitator. The stainless steel wires of 0·006 in. diameter which form the charged electrodes are spring-loaded and attached by hooks to a honeycomb-shaped aluminium framework at each end of the tube assembly. Each supporting frame is separated from the main structure by six cylindrical insulators 2 in. long x $\frac{1}{2}$ in. diameter. Welded to a flange on the base plate is a $4\frac{1}{2}$ in. high 18 s.w.g. aluminium skirt which guides the smoke from the chimney opening into the tube assembly. To stiffen this skirt, there are two 0·25 in. swages at approximately 1·5 in. from each end. Six aluminium struts of $\frac{3}{8}$ in. o.d. are positioned between the end plates near their outside edge, to preserve the rigidity of the structure. In the version of the precipitator illustrated, the centre tube is removable, so that smoke samples may be chemically analysed. The outside dimensions are 25 in. high x 13 in. diameter and the surface area available for collecting smoke is 36 sq. ft.

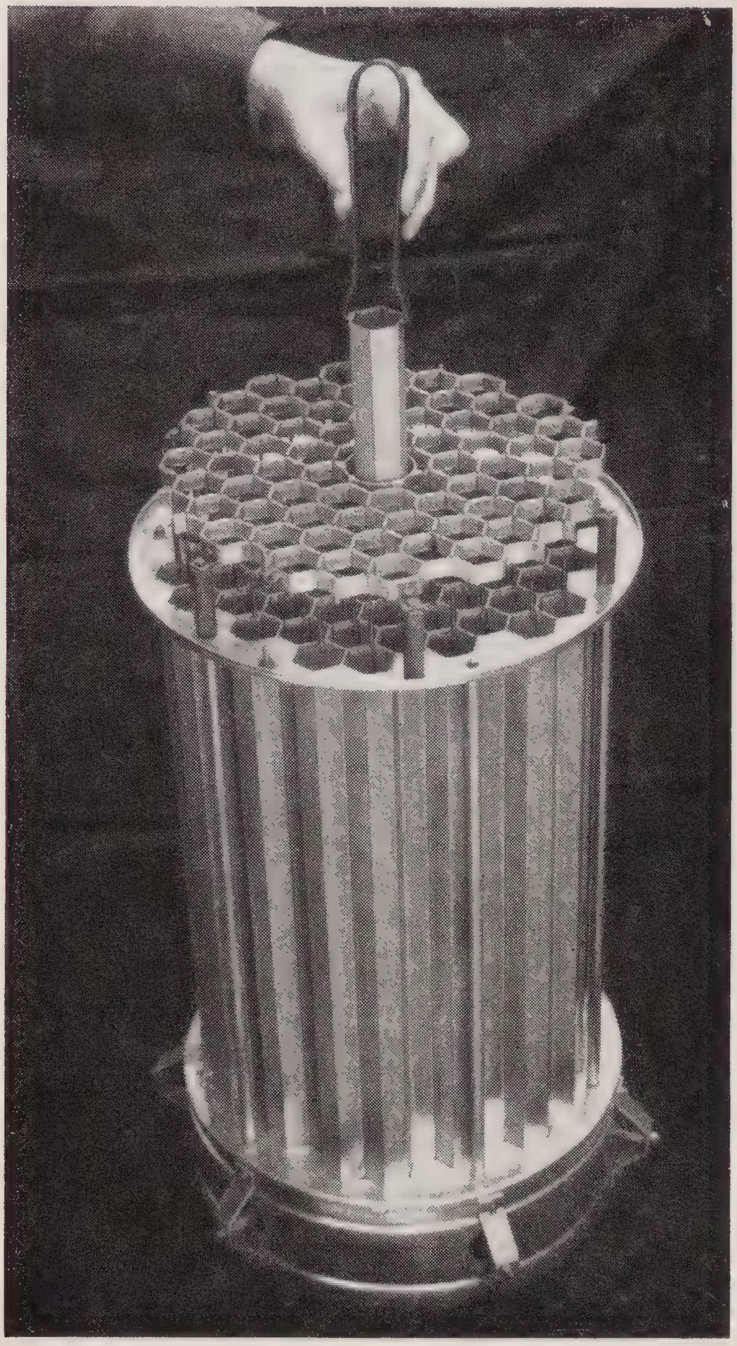

Fig. 2

The complete instrument weighs only 15 lb.

It is extremely important to ensure accurate wire location, as the sparking potential is determined by the worst centred wire. This is achieved by using a wire-support frame made from 0·5 in. long sections of the hexagonal tube, welded together to form a honeycomb as shown in Fig. 3. Before welding, a flat is filed on the apexes of each hexagon so that when they are assembled, small holes are formed at their points of juncture, through which the wire-support hooks can be passed. The frame is then mounted so that the vertical axis of each tube is in line with the corresponding hook. The frame is attached to the insulators by angle brackets and slotted fixing holes allow adjustment of the assembly for final wire centring. The position of the top frame when attached to the precipitator may be seen on Fig. 2. In this version there is a circular hole of diameter $1\frac{3}{4}$ in. in the frame, carrying a movable hook support, which permits the removal of the sampling tube.

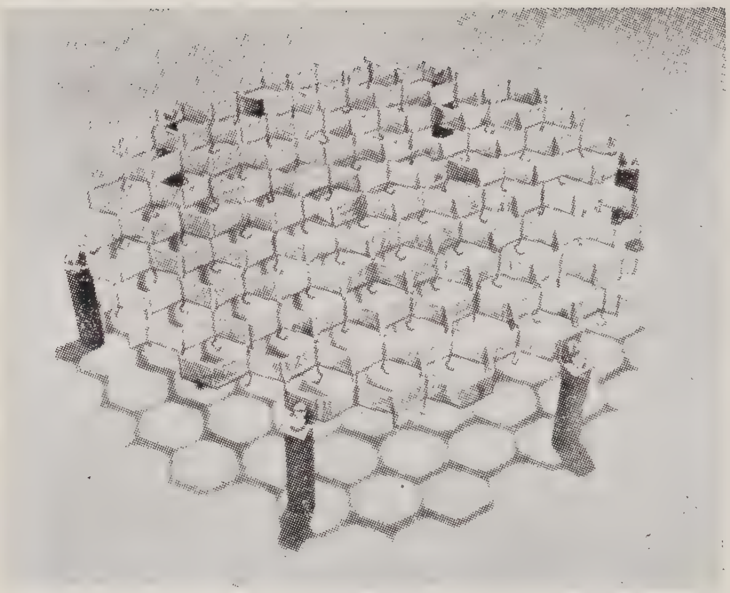

Fig. 3

The lower wire support frame is identical in design, but in this case aluminium cups are attached in place of the angle brackets. The insulators, which are of the same dimensions as the upper ones, are a pushfit into these cups, and are brought out through holes in the skirt to fit into similar cups held in 18 in. s.w.g. aluminium brackets. The bottom insulators are exposed to dirty gases and unless precautions are taken they quickly become coated with a deposit, which may lead to electrical breakdown. For this reason, the insulators are made to protrude from the holes in the skirt, so that for most of their length they are out of the flue gas stream. Further, the base of the precipitator is maintained under slight suction, and the air flow in through the holes prevents any appreciable deposition. The lower wire support frame is inside the skirt and is not visible in Fig. 2, but four of the six insulators protruding through the holes in the skirt and attached to the supporting brackets may be seen.

Performance

By examination of the flue gases emerging from the precipitator, the authors have shown[5] that it is capable of removing more than 97% of the smoke from a charge of coal on a domestic appliance under normal operation. It is therefore an ideal standard of reference for the gravimetric measurements of domestic smoke.

Some measurements of the smoke emission from a typical bituminous coal will be described in a paper later in the Conference,[6] together with the method of using the precipitator and the high voltage, cleaning and weighing equipment which have been developed for its efficient operation.

Acknowledgments

The work described in the paper forms part of the research programme of the British Coal Utilization Research Association and is published by permission of the Director-General.

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SOME MEASUREMENTS OF THE SMOKE EMISSION FROM DOMESTIC APPLIANCES

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SUMMARY: The smoke emission from a number of domestic appliances has been investigated under various conditions, using a recently developed electro-precipitator which collects more than 97 per cent of the smoke. A typical inset open appliance and bituminous coal have been chosen as standards for the purposes of comparison. A full account is given of the mode of operation of the precipitator and tests are described which establish that combustion rate, method of refuel and appliance design all affect the percentage smoke emission.

Introduction

Various workers in the past have investigated smoke emission from domestic appliances. There has, however, been surprisingly little systematic work in this field, and when the electro-precipitator described in an earlier paper[1] of the Conference, was designed and proved, it was decided to use it to establish the smoke emission from various fuels and appliances. This work is still continuing and much remains to be done. The results quoted in this paper will, however, serve to illustrate how the new instrument can be applied to investigations into the "smokiness" of appliances and fuels.

Appliances and Installation

Selection of Typical Domestic Open Fire

One of the problems which must be faced when legislating for smoke reduction is the degree of reduction which is practicable and economically feasible. Before a figure can be placed on this, it is necessary to know the existing smoke emission. For this reason, one of the first uses of the precipitator was to establish what may be regarded as a norm for domestic smoke emission; the smoke evolved by a simple open fire burning bituminous coal. For this purpose an inset grate, chosen from the list of recommended appliances,[2] was selected together with an East Midland coal, Gedling Top Hards, in Trebles size grading. This coal has a volatile content of 38·5% (D.M.F.) and is typical of a large proportion of the coal supplied on the domestic market. It has the further advantage of being the coal adopted as a standard for appliance testing.[3]

The appliance was installed in a standard brick setting, conforming to C.P. 403 (1952). This, in turn, was surmounted by a 9 in. x 9 in. brick chimney terminating 15 ft. above hearth level. A wide ducting, situated vertically above the chimney, removed all the flue gases issuing from it. When the precipitator was not in position, slight suction was applied by a fan in the ducting. As there was a space of several inches between the top of the chimney and the bottom of the ducting, the effect of this suction on the natural flow up the chimney was negligible.

Freestanding Convector Fire and Openable Stove

For comparison with the tests on the simple open fire, experiments were also undertaken using a freestanding convector fire and an openable stove, both chosen from the list of recommended appliances.[2] The setting and fuel used were the same as those described in section 2.1 for the tests on the simple open fire.

Experimental Procedure

Refuelling Technique

For the measurements with the simple open fire, two refuelling procedures were adopted. The first was based upon the standard test procedure for domestic appliances,[3] in which the fire must be refuelled to a predetermined level at 90-minute intervals. Thus, as burning rate increases, the weight of the refuel becomes greater. In the second procedure, an approximately constant refuel weight of 3·0–3·5 lb. was employed, the time between refuels being varied according to burning rate. This second mode of operation was thought to be nearer to normal domestic practice.

A series of measurements was made with each refuelling technique, covering a wide range of burning rates. In both series the fire was allowed to become well established before measurements commenced. The test period then consisted of four refuels, the precipitator being used to measure the smoke from two of these.

For the tests with the convector fire and openable stove, measurements were made at a range of burning rates, using only the constant weight refuelling procedure. All tests on the stove were carried out with its doors closed.

Method of Operation of Precipitator

Immediately before refuel of the fire, the precipitator was weighed on a modified commercial balance, capable of weighing up to 20 lb. with an accuracy of 1 part in 10,000. It was then placed at the top of the chimney on a short metal ducting which increased the flue area to a circular section of 13 in. diameter with minimum disturbance to flow. A large cowl, connected to a ducting from the suction side of a fan, was drawn down over the instrument and a damper in this ducting was adjusted until the flue gas volume flow was restored to normal. The precipitator was then raised to a high operating potential (about 8kV) using a power unit with a rating of 40mA and 15kV, and the fire was ready for refuel.

As soon as smoke emission had started, the operating potential of the precipitator was lowered momentarily until smoke was seen to be escaping from the instrument. The potential was then raised from between 1 to 2kV above this level. Although this procedure was somewhat arbitrary and depended to some extent upon the experience of the operator, inspection of the precipitator at the end of the period of emission showed whether the top few inches of the tubes were clean and the precipitator was working at maximum efficiency.

After smoke emission had ceased, the instrument was removed, allowed to cool to room temperature and re-weighed. The amount of smoke deposited was found by difference. Two or three hours were usually allowed for cooling, the final weight being taken as that obtained when three readings at ten-minute intervals showed no difference. This procedure was necessary as the precipitator when first removed holds a relatively large volume of hot air which introduces an appreciable error into the measured weight of smoke.

For the removal of the smoke deposit after weighing, two types of cleaning apparatus were necessary. The carbonaceous deposit produced after flames had broken through at the fuel bed was extremely flocculent, and under some conditions occurred in such volumes as almost to block the precipitator tubes. It had therefore to be removed after each test. For this purpose, a hose from the suction side of a fan was coupled to one end of the electro-precipitator by a linen connector. A high-pressure air jet was then directed down each tube in turn until the loosely adhering soot was all dislodged.

The tarry products which constitute much of the smoke produced by domestic appliances presented a rather more difficult cleaning problem. Although it was found that deposits of this kind could be accumulated for a number of tests without hindering operation, the electrical performance of the precipitator was ultimately affected and the tarry material had to be removed. This was done by immersing the complete instrument in a solvent. Some difficulty was encountered in finding a suitable solvent, but eventually a mixture of equal parts of Sextone B (monomethylcyclohexanol) and methyl alcohol was found to be completely satisfactory. Some care had to be taken, as prolonged immersion in the solvent led to corosion of the aluminium from which the instrument is constructed. The solvent itself is not corrosive, but was made so by the various deposits removed from the instrument. Hence, the worst of the deposit was removed by immersing the precipitator for about 10 minutes in one lot of solvent, and the remainder was removed by immersion in relatively clean solvent for a further period of not less than 20 minutes.

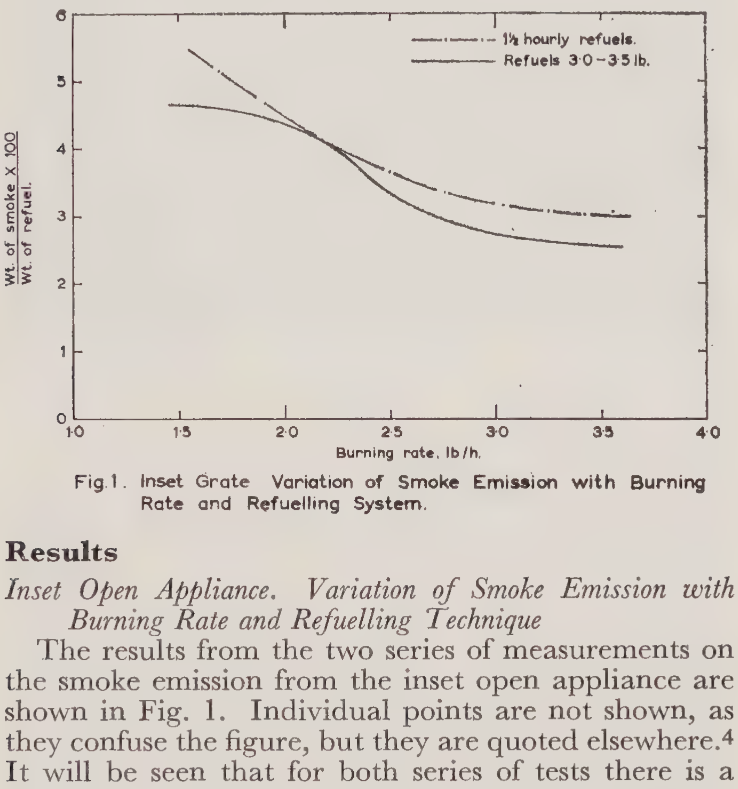

Fig. 1. Inset Grate Variation of Smoke Emission with Burning Rate and Refuelling System.

Results

Inset Open Appliance. Variation of Smoke Emission with Burning Rate and Refuelling Technique

The results from the two series of measurements on the smoke emission from the inset open appliance are shown in Fig. 1. Individual points are not shown, as they confuse the figure, but they are quoted elsewhere.[4] It will be seen that for both series of tests there is a marked variation of percentage smoke emission with the mean burning rate, although the curves are slightly different in shape for the two methods of operation.

At higher burning rates the refuels for the 90-minute refuel tests are larger than those in the other series. It is to be expected, therefore, that the smoke emissions will be lower for the latter, as flames will break through the fuel bed before much distillation smoke has been emitted. This is confirmed by the results. At burning rates of less than 2 lb./h., where the 90-minute refuels are lower, a similar argument would lead to the conclusion that the smoke emission for these tests should be the smaller. They are, on the contrary, significantly larger, and the explanation probably lies in the fact that in the 90-minute refuel tests at these burning rates, the combustion zone had not reached the top layer of the fuel bed when the refuel was made. Consequently, a relatively large weight of distillation smoke was emitted before the fuel bed had become sufficiently hot for flames to break through. Between the burning rates 2·1–2·2 lb./h. the two methods of refuel are identical and the two curves coincide.

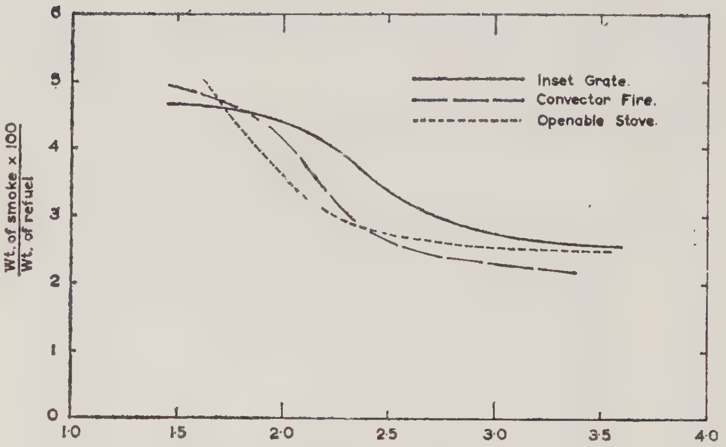

Fig. 2. Comparison for different Appliances of Variation in Smoke Emission with Burning Rate

Variation of Smoke Emission with Appliance Design

The results from the two test series using the freestanding convector fire and openable stove are compared in Fig. 2 with the constant refuel weight tests on the ordinary open fire.

At low burning rates the smoke emission from all three appliances are very similar, being approximately 5% at 1·5 lb./h. As the burning rate increases, the smoke emission from the stove and convector fire tends to decrease rather more rapidly than that from the open fire; but at the highest burning rates employed the open fire and closed stove again have smoke emissions of the same order. The convector fire, however, has a slightly lower emission.

For appliances like stoves and freestanding fires there is no such thing as a typical appliance, and it is possible that, had different appliances been used, different results would have been obtained. The similarity between the smoke emission from three such widely different appliances is, however, striking and does suggest that updraught combustion in domestic grates produces much the same amount of smoke irrespective of the conditions over the fuel bed.

Conclusions

Using the electro-precipitator developed in the Domestic Appliance Laboratories of the B.C.U.R.A., it has been possible to establish the level of smoke emission from conventional bituminous fuels in conventional appliances. Work is now in hand upon other aspects of the problem—in particular a study of the variation in smoke emission with the volatile content of different fuels. Studies are also being made of the effect of various devices for reducing smoke emission.

This new work has been greatly stimulated by the development of an instrument for the accurate gravimetric measurement of domestic smoke, and the electro-precipitator is now being used for similar purposes in several other laboratories concerned with the problem of domestic smoke emission.

Acknowledgments

The work described in the paper forms part of the

research programme of the British Coal Utilization Research Association and is published by permission of the Director-General.

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DOCUMENTATION OF AIR POLLUTION REQUIRES INTERNATIONAL CO-OPERATION

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SUMMARY: The department for documentation of the Verein Deutscher Ingenieure has established a system of documentation of air pollution. A system of classification has been worked out and is described. An international exchange of documentation is suggested and steps towards such an exchange are outlined.

Two years ago, the department for documentation of the Verein Deutscher Ingenieure (VDI) in Dusseldorf established a special documentation on " Air Pollution ". It is their task to compile material with an indication of the authorities used, covering the whole field of air pollution, and have it registered, so that it is possible to answer even very specialized inquiries.

First it had been considered how the sphere of work was to be defined. Our documentation of air pollution is limited to such pollution which has actually an effect in a free atmosphere. Publications pertaining to such fields connected with air hygiene questions in factories, interiors, or underground in the mining industry, industrial hygiene and air conditioning, are only being taken into consideration in case they might be of importance for open air hygiene. We also think that radioactive air pollution does not belong to our field of activity.

An efficient register of titles of publications requires a well divided classification. After several tests we have developed the following division:—

0. General.
1. Measuring technique, sampling procedure, and analytical methods.
2. Emission, atmospheric diffusion and degree of air pollution.
3. Effects of air pollution.
4. Plants and processes to reduce air pollutions.
5. Hygiene and sanitary technique, city planning and industrial-plant location.
6. Economy, legal and administrative questions.

A comprehensive subdivision and numerous common auxiliaries make it possible to characterize quite specifically the contents of each publication.

A further significant feature of the classification system is the additional characterization of the types and sources of air pollution which were treated:—

Types of Air Pollution

A.1	Inorganic substances.
A.2	Organic substances.
A.3	Emission of special plants and processes.
A.4	Smelling substances.
A.5	Natural air pollutions, aerosols.

Sources of Air Pollution

Q.1	Furnace and combustion.
Q.2	Industry and trade.
Q.3	Traffic.
Q.4	Natural Sources.

These divisions are again comprehensively subdivided so that all papers on a certain component of air pollution or on the emissions of certain plants can immediately be seen from the register of titles.

The titles taken from about 150 reviews are encoded according to description. An extract of the results is currently published in the review " Staub ".

The quantity of publications in the complex field of air pollution, particularly the great number of reviews issuing them, does, however, exceed the capacity of the smaller documentation offices. For a continuous and more or less complete selection of all results it is necessary to apply unusual means. However, an international co-operation of national documentation offices would have a favourable influence on covering as much literature as possible, at reasonable expense.

The ideal plan would be as follows: The national documentation offices of each country should peruse their own literature and extract the titles therefrom, and the results should be distributed via the central office amongst all parties concerned. Such an organization, however, can only be established step by step. This is the way we tried to work out:—

1. First of all, those offices dealing with the documentation of air pollution, and which should be interested in international co-operation, will have to be discovered.
2. By mutual exchange of ideas the field of activity to cover the documentation should be defined.
3. A list of the most important reviews in the field should be established and the perusal and extraction of titles should be allotted to the various participants. Each country which is represented should extract the titles of its own literature. Literature from countries not represented should be distributed by agreement.
4. The organization of the exchange should depend upon the number of participants. In case there are only a few partners, a two-sided exchange of all of them with all of them would be possible. Since it is, however, desirable to get as many countries as possible to co-operate, the establishment of a central office would be appropriate.
5. As to the manner of passing on the collected titles, detailed deliberations would be necessary in the following respect:—
    - (a) Should only the lists of titles be exchanged, or titles with short summaries or descriptions, or titles with codes? (U.D.C.-numbers or own system?)
    - (b) Shall the titles be written consecutively or index cards? (What size?)
    - (c) What language should be used for communication?
    - (d) What are the periods for the exchange? The VDI-Documentation Department would suggest: Exchange of titles with a short summary or descriptions on index cards at the international size of libraries (75 = 125 mm), in German, English or French language, monthly issue.

V. 66

CURRENT STATUS OF AIR POLLUTION RESEARCH IN THE UNITED STATES

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SUMMARY: Air pollution research in the United States is substantial and is financed mainly by government funds. It has reached its present level only in the last three years. A great deal of effort is being concentrated on vehicular pollution as exemplified by Los Angeles " smog ". Work is also progressing on basic studies. A particular characteristic is degree of concern with analytical methodology. Intensive studies of health effects are being undertaken and are described.

The air pollution research effort of the United States is substantial, is financed mainly by governmental funds, and is distributed among 11 governmental, 39 university, and 18 research institute and private laboratories. The total number of independent projects is approximately 140. Approximately 350 full-time and 400 part-time workers are engaged in the total effort. The laboratory conducting the greatest number of projects is the Robert A. Taft Sanitary Engineering Centre of the United States Public Health Service.

Our national air pollution research effort reached its present activity level only within the past three years, the big increment occurring after the enactment in mid-1955 of the Federal Air Pollution Research and Technical Assistance Act. To guide this effort, the United States Public Health Service, which is charged with the responsibility for administering the act and the research funds appropriated thereunder, held national air pollution research-planning seminars in 1956 and 1958. In 1958 a general conference, attended by a thousand people, reported to the Nation the status of the problem and the steps being taken to cope with it.

The major emphasis in air pollution research in the United States is on studies which relate to the type of air pollution exemplified by Los Angeles " smog." Since many of the factors contributing to this type of air pollution are increasing in all large metropolitan areas in the United States, the results of this research will enhance our understanding of present and potential problems throughout the country.

Automobile Exhaust

The majority of these projects deal with the role of the automobile as a smog source. Studies on the design of both catalytic and noncatalytic afterburners for automobile exhaust gases and of induction type control devices are under way by the three largest United States automobile manufacturers and by private organizations specializing in combustion problems. Much of the actual research is being done at sites remote from our west coast.

Because fuel composition and engine design, maintenance, and use pattern are all suspect as factors contributing to smog formation, the effects of these variables are now under study in a number of laboratories and by the automotive and petroleum industries. Several of these same groups are also assessing the effects of automobile and environmental variables—photochemical energy supply, reaction time and dilution—on eye irritation in human test groups, on plant, animal and bacterial life, on visibility reduction, and on the chemical substances present. It is axiomatic that these studies all have implicit in them intensive research on sampling, analytical, instrumental, and test methods.

A corollary to this effort is current research emphasis on other hydrocarbon and nitrogen oxide sources, namely, solvent evaporation, petroleum refining, and the burning of fuel oil, natural gas, and several kinds of wastes. Included is intensive research on domestic, municipal and industrial type incinerators.

Basic Study

Despite our apparent preoccupation with Los Angeles smog, research of more direct benefit to cities elsewhere in the nation is not being neglected. We are making real progress in better understanding the role of meteorological and topographical variables in the accumulation of pollutants in community air, in our ability both to predict meteorological conditions conducive to excessive pollution, and to establish criteria for locating industrial zones and individual plants.

Nor are we neglecting the fundamental research areas basic to the measurement of air pollution and to the design of control equipment. Research is under way on the fundamentals of the filtration and scrubbing of aerosols, on many facets of chemical analysis for pollutants, and on automatic instrumentation based on both physical and chemical methods. One of the characteristics of our air pollution research is the degree of concern with analytical methodology. Specific examples are new methods for inorganic compounds such as sulphur dioxide and hydrogen chloride, and techniques for the identification of organics, with particular reference to the polynuclear hydrocarbons.

We have a National Air Sampling Network to provide basic data on air quality. A precipitation sampling and analytical scheme similar to that in Europe is undergoing field trial. A comprehensive air pollution survey of a community, similar to that conducted at Leicester, was completed earlier this year in Nashville, Tennessee. The findings are currently being analyzed. This study follows earlier ones completed in Louisville, Kentucky, and in the Detroit, Michigan, and Windsor, Ontario area, comprehensive reports on both of which have recently been published.

There is little research under way on problems associated with the burning of coal. The principal studies are parallel investigations by a coal trade association and a governmental laboratory of the means of SO_2 removal from flue gas. The principal industrial groups sponsoring some air pollution research are the paper and pulp, phosphate rock, and steel industries, and the automobile and petroleum industries previously mentioned.

Health Effects

Broadly, two main courses of action are being pursued simultaneously in the health studies. The first concerns morbidity and mortality statistics of communities to determine if aberrations in health patterns occur, and if they are related to air pollution. The second course is to define the biological or health effects of single and multiple known or suspected constituents of air pollution. This dichotomy covers both the epidemiological and laboratory experimental areas of study.

Working on the soundly based hypothesis, the irritation of exposed membranous body surfaces is the most important biological effect of community air pollutants, we early began the search for evidence of lung function changes due to such irritation in both the experimental laboratory on animals and in the field among humans.

In the area of epidemiology we have explored the following:

1. The town of Donora, Pennsylvania, which had a severe episode of air pollution in 1948, has had its population re-studied recently to assess the current health status of the population in the light of the previous episode of a decade earlier;
2. In another city, one in which coal smoke is the principal air pollutant, the health status of the population is being evaluated;
3. Mortality records of a large number of cities have been correlated with each other, using a number of death causes selected as possibly related to irritant air pollution;
4. Morbidity records of select large population groups are being studied in relation to place of residence, the latter being used as an index of air pollution degree.

In contradistinction to these *broad* epidemiological studies, others are concentrated on specific diseases and disease groups. One set of such studies is concerned with the disease entity of "chronic bronchitis." Another is concerned with " bronchial asthma," while a third group involves groups of patients suffering from defective lung function as a result of a multiplicity of diseases of which pulmonary emphysema is outstanding. In all of these investigations the search is aimed to determine whether the clinical disease (or its sympton complex) is modified by existent air pollution.

Animal Experimentation

Studies of animals in laboratories are under way using two basic approaches:

1. Known or suspected single or multiple air pollutants are examined to determine their effects upon animals;
2. Animals are allowed to live out their lives exposed to the same kind and degree of air pollution to which humans are naturally exposed in select urban areas.

In the first group of studies, major emphasis is given to pollutants which have their origin in the automotive vehicle. The major exception to this is the work on oxides of sulphur.

Although the primary purpose of the animal experimental studies is to provide information on how to search for adverse health effects of air pollutants on humans, such studies also provide significant leads as to the mechanisms involved in the health effects. These latter areas of investigation must not be neglected, once they are uncovered, for they and possibly they alone—may tell us of how to avoid the harm. Such apparent deviations from our main purpose may seem at times to lack purpose. The result may, however, be of great ultimate value. Our studies of enzyme chemistry, of tissue (and cell) cultures and of allergen-production of single (and multiple) air pollutants all fall into this category.

Cancer Studies

The relationship between cancer and air pollution is being studied both epidemiologically and in the laboratory. Broad studies of human cancer frequency have already shown that lung cancer is more likely to occur in the large metropolitan areas than in rural areas. The intensity of urbanization and the intensity of air pollution are assumed to have generally parallel developments. The validity of such a conclusion is being tested.

Among the studies in this area of interest are how potential airborne carcinogens may cause lung cancer; the significance of the phenomenon (and desorption) of carcinogenic vapours on aerosols; the phenomenon of bronchial epithelial irritation; and the importance of bronchial epithelial metaplasia among humans.

The final area of research concerning the medical aspects of air pollution, infectious diseases of the respiratory airways, is receiving only a moderate amount of attention at this time.

The future direction of air pollution research in the United States will continue to be to provide the answers to the four fundamental questions: What is in the air? Where does it come from? What does it do? and, How can we control it?

SOME THOUGHTS ON INTERNATIONAL CO-OPERATION IN AIR POLLUTION RESEARCH

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SUMMARY: Advance in the control of air pollution depends on more research and on much swifter and wider dissemination of the results of research and practical measures, technical and legislative. These in turn call for: (1) An international research journal which can be met by the Journal of Air Pollution. (2) An adequate international abstracting journal. (3) Preparation by W.H.O. of details of research in progress. (4) Periodical international conferences, which seems to require an international association.

There will be no argument that a greatly increased volume of research is essential for the elucidation of the effects of air pollution and for devising methods for preventing this pollution. In a topic like this the research will be pursued in many fields—medicine, chemistry, physics, engineering, biology, meteorology, statistics, etc.—and it is impossible for any single worker to have access to, still less to read, the many periodicals in all these fields. What is required is an international research journal and an international abstracting journal dealing with air pollution.

Already the new *Journal of Air Pollution* is making its mark as the international research journal and I should like to draw attention to this journal so that it may become the recognized medium of publication. The Editors of this journal have also embarked on a series of review articles which will be most valuable in sketching in the present background of knowledge.

The journal has also made itself the vehicle for notes of air-pollution research in progress in various countries. This is a particularly important activity and, in my view, should be systematically undertaken by an international body. In many countries air pollution is perhaps the most important public health problem and it would be appropriate for the World Health Organization to take the lead in spreading information about research in progress.

Until recently the Fuel Research Station of the Department of Scientific and Industrial Research provided an excellent series of abstracts, but these have now ceased publication. The Air Pollution Control Association of America publishes monthly abstracts which, at the present time, provide the only reasonably complete monthly abstracts. The U.S. Public Health Service's monthly Public Health Engineering Abstracts is less complete, though valuable. The medical aspects of air pollution are to a certain extent covered by abstracts in the *Bulletin of Hygiene* and in *Excerpta Medica*.

Finally I must not forget to mention the abstracts published by this Society in its journal *Smokeless Air*. But these are the products of the industry of one or two individuals only and it is not reasonable to expect a voluntary society with a very small staff to undertake a complete abstracting service. It is difficult to see a solution to this problem. The cost of commercial abstracting journals is very high and their success must depend on a large body of readers. It is doubtful whether an abstract publication for air pollution would command a wide readership. I see no alternative to a subsidized abstracting service unless it be provided co-operatively by an international air pollution control association, which I intend to mention later.

The ills from air pollution suffered by the nations of Western Europe and by those of North America can be avoided, and the solutions they have found applied, by countries whose industry is now developing rapidly only if there is adequate communication of experience. I have always found colleagues in Europe and America most friendly and helpful in letting me know about their work, and personal contact of this kind is the most valuable but it must always be relatively limited. The *Journal of Air Pollution* and the abstracting service I have suggested can only to a degree take the place of personal contact with its clash of opinion and active debate. In many fields of research there are now periodical international conferences, commonly organized by international bodies. An example which we may mention here is the triennial International Congress of Pure and Applied Limnology. The analogy is quite a close one since limnology covers a number of disciplines: botany, zoology, chemistry, physics, etc., and because the number of people interested is not greatly different. This Congress is organized under the auspices of the International Association by the national body of the country where the Congress is being held. The Secretary of the International Association, who is also the editor of the Congress Proceedings, is a zoologist of the Freshwater Biological Association at Windermere. All officers are honorary and the organizational expenses are low.

I feel strongly that there is need for a similar international congress on air pollution control—to be held every 3–5 years. This congress should permit the discussion of recent relevant research in the physical and biological sciences, of legislative and administrative control measures, and of engineering and technical methods of reducing air pollution. I invite this International Conference to express its interest in this idea so that perhaps the officers of the existing national societies may be prompted to get together to discuss my suggestion.

If such an international association were to be formed it might be possible for national societies—or individuals in countries without a national society—to prepare abstracts of their own country's literature which could then be joined to form a co-operative abstracting service.

May I summarize these "idle thoughts of an idle fellow." Advance in the control of air pollution depends on more research and on much swifter and wider dissemination of the results of research and practical measures, technical and legislative. These desiderata in turn call, in my view, for:

1. An international research journal, which need I feel can be met by the *Journal of Air Pollution*.
2. An adequate international abstracting journal.
3. Preparation by WHO of details of research in progress.
4. Periodical international conferences, which seems to require an international association.

STEPS TAKEN BY LOCAL AUTHORITIES IN THE FEDERAL GERMAN REPUBLIC TOWARDS COMBATING AIR POLLUTION

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SUMMARY: In Germany the number of complaints about air pollution is increasing, probably as a result of public awareness as well as an actual increase in pollution. German local authorities regard it as their duty to protect their population, by means specified in the paper. Investigations into the nature and sources of pollution are being undertaken and one investigation (in the Oberhausen district) is described. Arising from these investigations, several lines of policy for local authorities are suggested. The paper concludes by outlining some of the provisions of a new Federal Bill.

Technical development, the expansion of industry and the concentration of its places of production on to towns and cities have had their share in making the increasing pollution of the air and its effects on man, beast and plant a world-wide problem for the population and local authorities.

Throughout the communities in the German industrial areas there are increasing complaints by the population about the intolerable pollution of the air. The reasons are probably also to be found in the press, radio and television campaign for the continuous enlightenment of the general public about the extent and the possibilities of their health being endangered by air pollution. The results of experiments are publicised, and Parliament intensively discusses a Bill for the improvement of the Law as it provides for the combating of air pollution at present.

Clean air is a health problem and also a technical, economic and legal problem—thus also a political problem for local authorities. On the strength of their constitutional status it is the task of local authorities in Germany to do everything for the well-being of their citizens by protecting them from detrimental effects or intolerable inconveniences caused by the pollution of the air. They, therefore, consider it their task to :

1. limit, within the technically possible, air pollution caused by urban installations (for example, power plants), for instance by electro precipitator installations;
2. take into account, particularly in town planning and new industrial plants and settlements, the achievements of dust techniques and air hygiene;
3. stress, in the course of individual negotiations with industrial companies, the necessity of on-the-spot or common measures aimed at the avoiding of smoke emission and immision.

German industrial towns are taking a particularly active interest in establishing fixed scales for emissions and immisions. For this purpose, they instigate investigations of the atmosphere and plants as well as the ascertaining of the total sulphur and sulphuric hydrogen contents of the air. Furthermore, investigations within plants and factories are being carried out by the Institute for Hygiene of the Water, Soil and Air by the Federal Ministry of Health at Berlin-Dahlem or the Institute for Hygiene of the Ruhr district at Gelsenkirchen in co-operation with supervising bodies, recognized experts and local industry. The sources of emission established in the course of these endeavours are probably similar internationally. They are:

1. industrial plants such as iron and steel mills, coke ovens, smelting furnaces (power plants, paper mills, cement works), particular refineries, casting installations, fish meal factories, institutions for the processing of animal carcasses, synthetic fibre factories;
2. small units, dwelling houses, petrol stations, garages;
3. communications, for example railways and motor-cars.

Dr. Schwarz and Professor Hettche report elsewhere on the various results of tests carried out.

Reference, here, is made only to some interesting results of the investigations carried out by the Health Office of the city of Oberhausen (together with the Institute for Hygiene at Gelsenkirchen) about the effects of air pollution on health generally, because they are in some respects related to the corresponding passages in the report of the Beaver Committee. As from the 1st June, 1957, technical measurements of air pollution have been taken simultaneously with ascertaining the state of health of certain groups of the population. These tests and investigations were carried out by way of a comparison between the industrial town of Oberhausen and the rural districts of Empel/Rees and Geldern. The guidance for these experiments was as follows:

1. comparable measurements of air pollution in the three areas;
2. clinical and x-rays examinations on all male babies born in the three districts between the 1st March and the 31st May, 1957 (some 900 altogether), in order to ascertain the number of cases of rickets;
3. at-random tests among 250 male children of twelve years of age in Oberhausen and, again, in the two rural districts together, as to occurrences of belated rickets;
4. testing of the picture of red blood particles in 20 per cent of all male state-school pupils (in all about 4,200);
5. special investigations, within the sphere of routine medical examinations in the fourth and eighth Forms at state-schools, among all pupils of these age categories as to the relation between the pupils' individual height and weight, the number of cases of bronchitis, injuries to the eyes and skin diseases (approximately 8,000 children);
6. finding out the number of cases of bronchitis and eye injuries among a group of the population (by drawing in the general practitioners, two-thirds of whom took part in the scheme, a group of the population estimated at more than 230,000 was represented; this part of the experiments and tests was carried out during the third quarter of 1957).

These were the results:

Taking the average at Oberhausen, the pollution of the air there was about five times as great as in the rural districts. The comparisons showed that there was a certain relationship of the absorption of the sunlight to the over-all conditions. At Oberhausen there were twice as many cases of rickets among the babies as among the babies living in the country.

Among twelve-year-old boys the serum-phosphorous elements were significantly higher in Oberhausen, and pathological features were only found to be in evidence in Oberhausen. The red blood picture in the cases of more than 4,000 examinations of male state-school pupils was significantly worse in Oberhausen. It was remarkable, in this connection, that the particularly heavy air pollution in the district of Oberhausen-Osterfeld reflected congruency with the particularly bad results of blood tests and phosphorous elements among the children at Osterfeld. The ten, eleven and fourteen-year-old children, respectively, were smaller and of less weight in all comparable groups at Oberhausen. With all children, in Oberhausen bronchitis was one-and-a-half times as frequent and eye injuries and inflammations of the eyes were nearly four times as often as among children living in the country. On the other hand, there were more cases of skin diseases in the country. Bronchitis among adults in Oberhausen was more frequent by 10 per cent than in the rural districts. The examinations revealed twice as many cases of eye injuries and inflammation of the eyes among adults at Oberhausen compared with the rural population.

In spite of numerous sources of error the strong tendency of the results (no other essential causes having been established) leads to the conviction that air pollution, in accordance with its characteristics must be held responsible for the symptoms of certain changes towards ill-health.

The actual extent of damage caused by air pollution to the state of health of the population cannot yet be established with exactitude in all its individual details —taking into consideration here the known and applied methods available today.

Similar examinations and investigations are contemplated, to be instigated in the industrial city of Leverkusen and the rural district of Rhine-Wupper. More examinations will take place among inmates of old people's homes and employees of a casting plant and a steel mill in the cities of Duisburg and Muelheim/Ruhr as to the dependence of the functioning of the lungs on air pollution through dust and gases.

The experiences gained in the towns and cities lead to the following suggestions for local authorities' policy:

(1) Provisions under the law are necessary for the admissible emission from exhausts of motor-cars;
(2) the outlines laid down by the VDI-Commission for Clean Air shall be regarded as minimum requirements according to Para. 25, Chapter 3, Point 3 of the Trade Law;
(3) further tax concessions in respect of installations for the prevention and elimination or diminution of air pollution (limited tax concessions are in existence up to 1960);
(4) regulations restricting the use of certain fuel stuffs;
(5) on the roads, a smooth flow of traffic—possibly without stopping points—should be made possible;
(6) more attention than before to be paid to the air-cleaning effects of parks, green belts and plants—especially in industrial areas;
(7) the German meteorological service should be entrusted with the task of informing industry of unfavourable weather (especially expected inversions) well in advance of its occurrence. It is particularly important that this information should be given to companies with considerable smoke emissions from their plants;
(8) the electrification of the Federal German Railways should be expedited;
(9) research should be promoted aiming at:
    (*a*) unified and appropriate methods of measurements and analysis;
    (*b*) complete burning of fuel stuffs without poisonous residue;
    (*c*) developing suitable installations for the cleaning of exhaust gases from fuel motors as well as for the cleaning of smoke from ovens and chimneys, respectively;
    (*d*) scientifically ascertaining the medical (or health) side of air pollution;
(10) more and larger plants supplying long-distance district heating, such plants being equipped with suitable dust eliminators; stoves and ovens emitting very little smoke only;
(11) the capacity of smoke and dust particles to hover in the atmosphere is influenced by the relative humidity of the air. It does, therefore, appear useful to sprinkle the streets in town centres and to lay-out artificial ponds linked with green belts;
(12) taking into account the depreciation in value of residential areas as a result of pollution of the air by dust and smells, as far as possible residential areas in a town should be planned for the west of the town, and industrial areas should be in the east;
(13) co-operation of District Health Offices, town-planning authorities, underground construction and garden culture (doctors, chemists, physicists, engineers, biologists) is important. It is furthermore essential exactly to survey and ascertain the climate of a town and the possibility of its being influenced by uneven street-areas (surface formation of the urban district, hills, mountains, valleys);
(14) creation of a more suitable and appropriate legal basis for a more effective combat against air pollution.

The German towns very much appreciate the draft of the Bill (Federal German document 301). (See Paper II. 17, by O. Schmidt). Under it, paras. 16, 25, 147 of the Trade Law (GewO) of June 21, 1869, in their wording of September 29, 1953, and para. 906 of the Civic Code (BGB) of August 18, 1896, in its wording of July 26, 1957, are to be amended. According to paras. 16 to 18 of the Trade Law (GewO) the specified installations, which may cause inconvenience to a neighbourhood or the public, respectively, are subject to special permission by the respective authorities competent under the laws of the land. The new Bill envisages to extract from the law the list of installations subject to permission and embody this list into legal regulations facilitating the more immediate adaptability of this list to the technical development. These new regulations will also serve the purpose of determining the technical requirements of the installations.

The Bill lays down the principle that the plant or installations shall be operated in such a manner as is possible and economically justifiable according to the trend of the technical development at any given time. By incorporating Point 2 into para. 906 of the Civil Code, this principle also applies to the Private Law (vide, as to the wording of this draft of the Bill, the report of the Inter-Parliamentary Working Committee). In addition, it is intended to make it a legal obligation for the owner of a plant or factory to allow a supervision of emission coming from his chimney, etc.

It is expected that Parliament will pass this Bill during the course of this year.

V. 69

PROBLEMS OF SMOKE EMISSION OF COAL-FIRED SINGLE STOVES

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SUMMARY: Experiments are being conducted on the emissions from domestic fire places. A modified version of the optical instrument developed by the Fuel Research Station, Greenwich, has been used. The authors seek opinions and information on this and on the question of separating the constituents of the flue gases, experimentally.

For two years, investigations have been carried out at the Ruhrkohlen-Beratung concerning the constituents of the flue gases emitted from domestic fireplaces. The mode of experimental procedure is as follows:

The stove to be tested is placed on a weighing machine recording the rate of combustion, and, during the heating-up period, the flue gases are led through a by-pass which is blocked as soon as a state of equilibrium has been reached, so that, from that moment, the flue gases pass through a measuring duct which has been brought to the same level of temperature by means of hot air. At first, the smoke density is measured optically. Optical smoke meters operate by measuring the voltage of photoelectric cells which voltage depends on the diffraction or absorption of the testing ray of light.

Our measuring instrument is designed on similar lines as the instruments of Fuel Research Station, Greenwich; these are described in detail in the publications BCURA No. 29 and *Journal of Scientific Instruments*, Vol. 33, pp. 495-2199. These show that the measuring is effected according to the null method. Starting from a monochromatic source of light, two rays of light are thrown on two photo cells so that only the difference of voltage is measured. Of the two rays of light, one is thrown through a flue and the other provides a smoke-free path. If there are solid particles in the flue gases, the ray of light going through the flue is dimmed and provokes a modification of voltage. A servomotor is caused to bring an optical wedge into the undimmed current of light so as to eliminate the difference of voltage. For our tests the null method is foregone and the difference of voltage between the two photo cells is recorded direct. The varying load curves of the photoelectric cells are a drawback, the quick indication (2 seconds) and the less elaborate apparatus are advantages.

When taking measurements, the quick changes of smoke density are to be noted and we should like to hear opinions as to whether a delay of indication by about 7 seconds does not unduly level the peaks. We have not yet gauged the smoke meter for the relation smoke density/grams of dust. In England, a neutral dense filter is used for that purpose. As flue gas is a mixture of soot, ash, coal, and tar of varying particle sizes, it is difficult to manufacture test dusts for gauging the filter. Which method has been applied in England? What publications have been made?

For the purpose of separating the solid constituents, an electrostatic precipitator has been inserted operating with tensions up to 30kV. We have found that, with higher temperatures, the degree of separation of the precipitator is reduced owing to the ionization of air. Which temperature of entrance into the precipitator is preferred by others in order to obtain a satisfactory separating efficiency? Especially when burning bituminous coal, the proportion of tar in the solid and the gaseous phase in the flue gases is considerable. The separation of this gaseous tar is difficult because complete condensation is not achieved on account of temperatures below the dew-point. By what means could the degree of separation be increased?

After the electrostatic separator partial quantities are extracted in order to test the gaseous constituents; the measurements are confined to CO, CO_2, CH_4, SO_2, H_2, and O_2. The measuring instruments are of commercial types, operating with chemical and physical methods. The quantity of flue gas is determined by means of a gas meter of the wet type.

The dust collected in the electrostatic precipitator has to be tested for soot, ash, fly coal, and tar contents. The quantities concerned amount to 0·5 to 10 grams of solid particles.

The tar may be separated by solvents which are necessary anyhow to clean the flue ducts and extract all dust for measuring purposes. The solvent containing the solid particles is filtered and the filtrate evaporated. The dissolved tar is retained. The residue should be tested for its constituents of soot, coal, and ash. We think that the quantities are too small for float and sink analyses. Optical methods are possible but require considerable labour. Which methods are usual in England?

We are particularly interested in optical methods which are suitable for routine tests and the results of which reach an accuracy of 3 per cent.

In order to be able to solve the problems connected with tests of this kind, we should like to obtain some knowledge of the work done and the experiences of other countries. We think that a regular exchange of experiences among those concerned with smoke abatement would lead to quicker and better results.

INVERSIONS AND AIR POLLUTION

P. J. MEADE, Meteorological Office, London, Great Britain

SUMMARY: The effects of inversion layers in the creation of high concentrations of pollution is often exaggerated. Their effects depend on their thickness, temperature gradient, position and the thermal properties of the surrounding air. Additional complications are introduced by the heights of any chimneys and the buoyancy and efflux velocity of the effluent. A number of examples are given, and it is concluded that high chimneys with buoyant effluents are advantageous, although occasional inversions would still defeat this advantage.

Introduction

When the waste gases produced by the combustion of fuel are discharged from a chimney their subsequent history is largely determined by meteorological processes. In problems of air pollution therefore the weather conditions are always important and frequently decisive. Among the factors involved in the transport and diffusion of gaseous effluent in the atmosphere, the inversion plays an important part and in fact the word itself has acquired a sinister meaning in the air pollution context. That this is so is an indication that the effects of inversions are frequently exaggerated to the point of error. An inversion when it occurs occupies a layer of the atmosphere and its effect on air pollution depends on the depth of the layer and the steepness of the (positive) temperature gradient in it, on the position of the layer in the atmosphere and on the thermal properties of the air in the adjacent layers.

Since an inversion comprises so many factors, it is an over-simplification to regard it as inevitably having an adverse effect on the normal distribution of atmospheric pollution. This is particularly true if we are considering not the pollution caused by a whole industrial area but that resulting from a single chimney stack. In such a case we have to take into account not only the characteristics of the inversion itself but also the height of the chimney and the buoyancy and efflux velocity of the effluent.

Thus the problem presented by inversions is by no means simple and clear cut, but it is possible by consideration of a few typical examples to estimate broadly the effects that may be produced in the majority of cases.

The Formation of an Inversion Layer and the Turbulence in it

In an inversion layer the temperature increases with height and this results from one of two main causes radiation or subsidence. At night the ground cools by radiation and then the air adjacent to the ground is cooled by conduction. A radiation inversion is thus formed and, according to the extent of cooling, the most favourable conditions being a clear sky with a calm or light wind, the inversion layer will have a depth of a few feet or several hundreds of feet. If fog forms at the ground, the base of the inversion is transferred to the top of the layer which will have a temperature gradient corresponding to conditions of slight lapse.

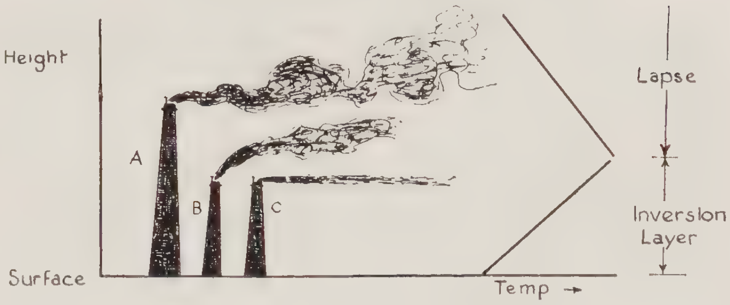

Fig 1. Inversion layer below, lapse condition above

A subsidence inversion is formed, usually well above the earth's surface, by the slow descent of air which becomes warmer by adiabatic compression since the descent is inevitably into a level of higher pressure.

In an inversion layer, whether caused by radiation or subsidence, turbulence is very slight and the vertical width of a plume will increase very slowly if at all. Horizontal spreading is also restricted but less so than in the vertical and, depending on wind strength, the plume spreads out very gradually and may travel for many miles with very little mixing with the surrounding air.

An Inversion Layer adjacent to the Ground

The first example is illustrated schematically in Fig. 1 which shows an inversion layer extending upwards from the earth's surface to a certain height above which the conditions are unstable, i.e. vertical temperature gradient negative. Plumes are shown originating from Chimneys A, B and C and, for simplicity, we ignore the question of downwash which can be dealt with in other ways.

Referring to Fig. 1, Chimney A is higher than the inversion layer and so the effluent is discharged into the unstable part of the atmosphere. Chimneys B and and C are of the same height and are wholly within the inversion layer, but the effluent from B is sufficiently buoyant to penetrate the inversion and enter the region of lapse or instability.

While the inversion lasts, the gaseous plumes from Chimneys A and B will not sink below the inversion top and so will not contribute to the pollution at ground level. On the other hand the plume from Chimney C will be carried horizontally downwind in a narrow highly concentrated stream which, when the inversion breaks down, may be brought quickly to ground level and cause heavy, though short-lived, pollution over a long distance.

This example of an inversion in a fairly shallow layer is therefore one during which high stacks make little or no contribution to the concentration of pollution near the ground while low-level sources, such as domestic chimneys, eventually cause much heavier pollution than the normal.

An Inversion Layer above an Unstable Layer

In the example shown in Fig. 2 the layer of air next to the ground is unstable and immediately above it there is an inversion layer. Chimney A extends into the inversion layer and the effluent travels horizontally as indicated. Chimneys B and C are, as before, the same height but the effluent from Chimney

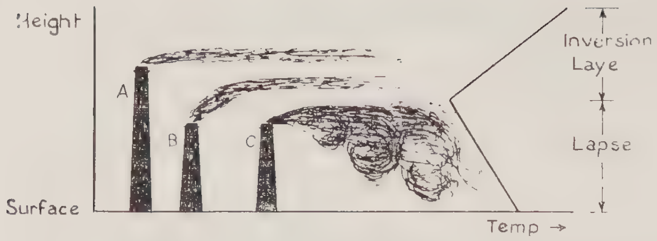

Fig 2. Lapse conditions below, inversion layer above.

B has enough buoyancy to penetrate the inversion, whereas that from Chimney C is not buoyant and is therefore confined to the unstable layer. While the atmospheric conditions of this example persist, the effluent from Chimneys A and B will have no effect on ground level concentrations, whereas that from Chimney C will undergo thorough mixing in the unstable layer and, since none of the effluent can penetrate the inversion, the concentrations reaching the earth's surface will be greater than usual.

In an example such as this one, much depends on the depth of the unstable layer which lies below the inversion. Oh the whole the high level sources have the advantage compared with, for example, domestic chimneys but on occasion the unstable layer may be sufficiently deep to prevent the escape of buoyant plumes from even the tallest stacks. When this occurs then all the sources will contribute to the pollution at ground level, depending on their rate of emission and on their effective heights. At large distances, however, the effect of the height of a source becomes progressively less important and the relative contributions of various sources depend mainly on output.

An Inversion with Fog below and an Unstable Layer above

Fig. 3 shows an example of a fog layer below an inversion which is itself covered by a layer of lapse or unstable conditions. Chimney A extends into the lapse layer and its effluent escapes into the atmosphere well away from the earth's surface. In the case of Chimney B, the effluent drifts horizontally without much mixing and its eventual history is determined by the manner of breakdown of the inversion layer. If it breaks down from above, the effluent finally escapes upwards. More commonly the breakdown occurs from below, following the clearance of fog, and a part of the Chimney B effluent may be brought to ground level in short-lived high concentrations some distance from the stack. The effluent from Chimney C is confined to the fog layer and a moderate degree of mixing gradually extending throughout the layer takes place. Some of the effluent therefore reaches the ground and the amounts increase temporarily as the fog disperses.

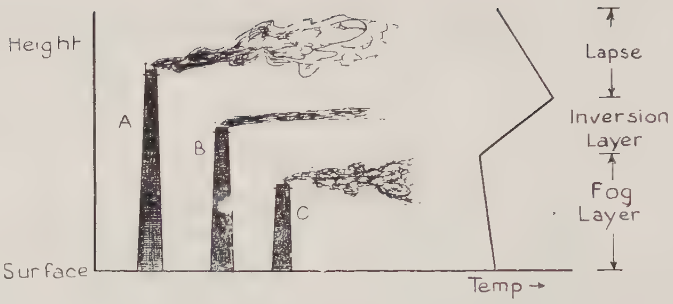

Fig 3. Inversion layer with fog layer below, and lapse conditions above.

Conclusion

These examples serve to emphasize the importance of taking into account the position and the depth of an inversion layer when considering the effects which inversions may have on different sources of pollution. The advantage of high chimneys are brought out but at the same time these examples suggest the need for realism in assessing these advantages. In Fig. 1, for example, Stack A itself penetrates the inversion. The effluent from Stack B does so because it has sufficient buoyancy but it might not do so if the inversion layer were deeper. The examples illustrated are typical but there could be wide variations in the depths of the different layers. Thus if all chimneys were high and emitting buoyant effluents, the evils of air pollution at ground level would be greatly reduced but from time to time an inversion would demonstrate that they had not been completely removed.

Acknowledgement

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EFFECTS OF EXPOSURE TO AIR POLLUTION ON COMMUNITY HEALTH

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SUMMARY: An investigation has been made of the effects of air pollution on mortality and morbidity in the city of Ube. The city of Hofu, was used as a control. The rates for a number of diseases and disorders of the respiratory and circulatory systems were found to be higher in Ube. The geographical distribution of mortality accords with the concentration of air pollution and of population, but not always with the industrial areas. There are also correlations between mortality and yearly, monthly and daily trends of air pollution. While there are other factors involved it is concluded that air pollution has at least some effect on the health of the community.

Amid the many activities of urban life, a scientific investigation of the chronic and cumulative effects of air pollution on the health of a community is a difficult problem. Air pollution, however, plays an important and significant role in determining the health of city people. In an attempt to clarify the problem, the writer has collated certain statistical information and the result is as follows:

A. The Geographical Phenomenon

As the control area of the city of Ube, we have made an investigation on the city of Hofu. These two cities are strikingly similar in respect of their urban and geographical conditions, and their meteorological conditions are especially similar. The city of Hofu, however, is not exposed to such intensive atmospheric pollution as the city of Ube, which suffers from a heavy concentration of pollution.

A comparative study of yearly mortality by selected causes in these two cities shows that in Ube city a high mortality rate was found for infants and the aged, while the death rate from diseases of the respiratory system such as diphtheria, pneumonia, bronchitis, asthma, tuberculosis, and lung cancer, and the death rate from diseases of the circulatory system such as heart disease are unusually high. In Ube city, for example, we find a mortality rate from diphtheria 7·8 times as high as in Hofu city; lung cancer is 2·4 times as high, heart disease one and half times. The geographical distribution of morbidity from diphtheria and from trachoma, and also of mortality from pneumonia, bronchitis and asthma among Ube citizens, is in accordance with the geographical distribution of the concentration of air pollution and of the density of population, but is not always in accord with the distribution of industrial areas.

B. Yearly, monthly and daily trend of the phenomenon

1. The yearly and monthly trends of the rates of incidence of diphtheria and trachoma, also the rate of absent sick pupils—especially the rate of absence from diseases of the respiratory system—among Ube citizens, is correlated with variations in the amount of deposited atmospheric impurity.

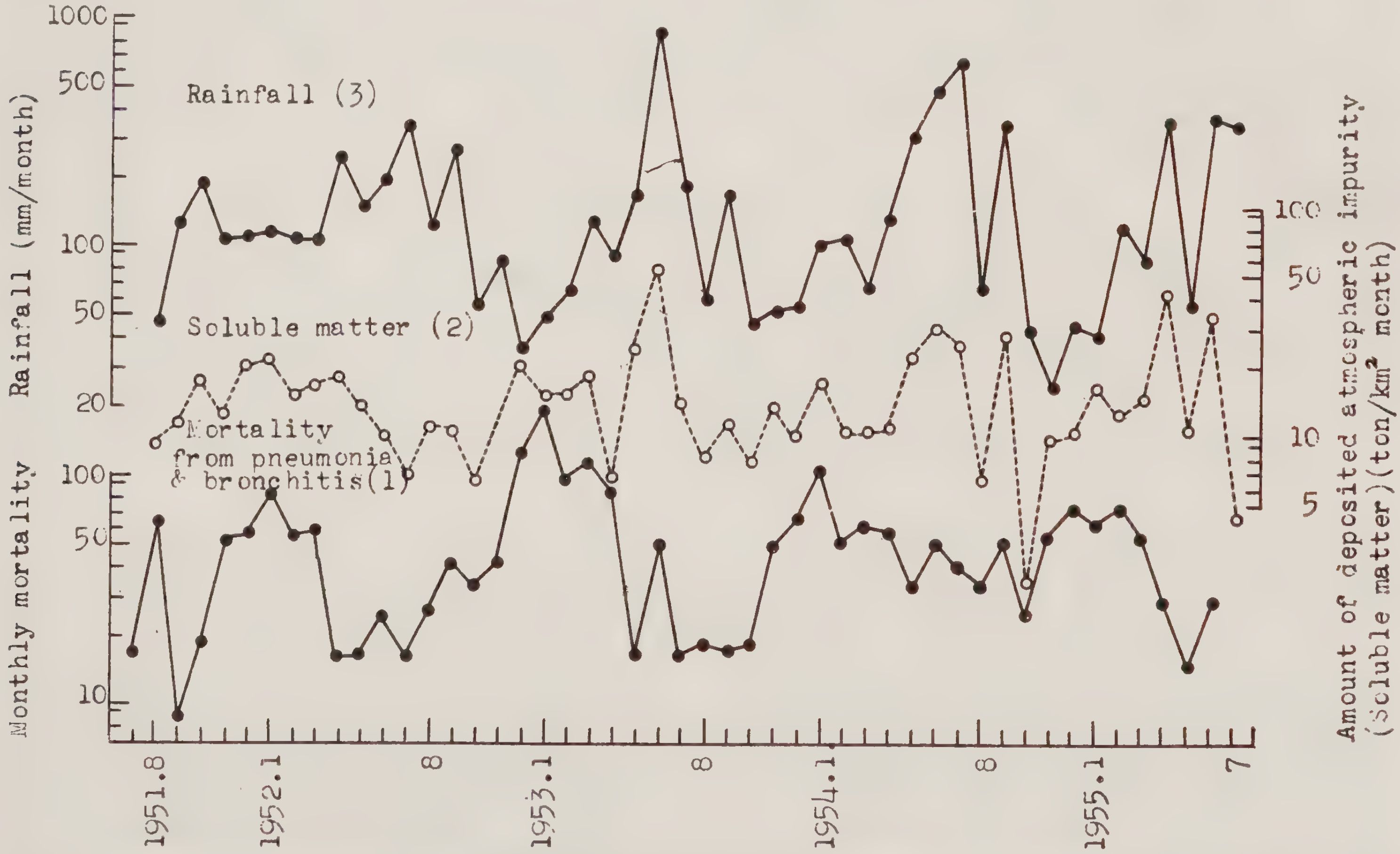

Fig. 1. Relationship between yearly and monthly trend of mortality from pneumonia and bronchitis, and deposited atmospheric impurity with meteorological conditions in Ube city.

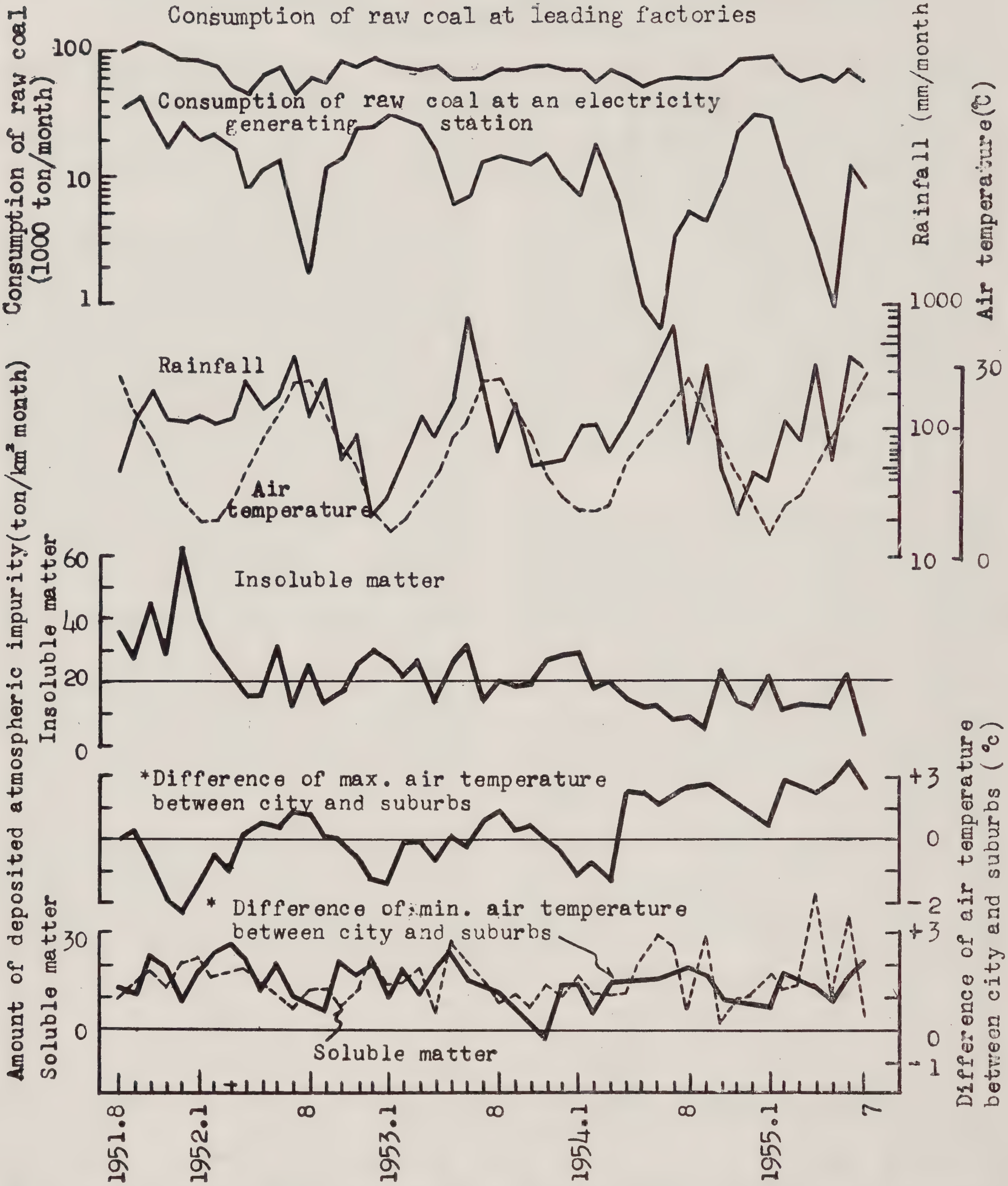

*Fig. 2. Relationship between deposited atmospheric impurity and consumption of raw coal with meteorological conditions in Ube city. Note: * Temperature at city minus that at suburbs.*

2. A comparative investigation of the correlation between the yearly and monthly variation of mortality from selected causes by month (1951–1955) and the climatic elements (air temperature and precipitation), among the citizens of Ube and among those of the control area, shows the following three items:

(A_0) Original monthly time series.

(A_1) Time series that eliminates " Trend " from original monthly time series.

(A_2) Time series that eliminates " Trend " and " Seasonal variation " from original monthly time series.

Each of these three items has a different direction and degree of correlation. The correlation between the yearly and monthly variation of monthly mortality by selected causes among Ube citizens, on the other hand, shows the positive correlation in each of these three items of A_0, A_1, and A_2, and the high rates of mortality are found in months when there is a high concentration of air pollution. The death-rates of the infant and of the aged, and death-rates from pneumonia and bronchitis show this phenomenon to a marked degree. (cf. Fig. 1–2).

3. The daily total of deaths in Ube city shows considerable increases either on the day when the concentration of air pollution (suspended atmospheric impurity) is highest or a day or two later. Consideration of this fact suggests that air pollution hastens the death of average patients, or hastens death of chronic invalids such as asthmatic or heart-disease patients among the aged and the feeble.

As there is a close relationship between air pollution in urban districts and climatic elements, and the relationship between mortality and climatic elements is also close (cf. Fig. 3), the previously mentioned relation between mortality among Ube citizens and air pollution, can not wholly be attributed to air pollution. It may, however, be said that directly or indirectly, air pollution has some effect on the health of a community.

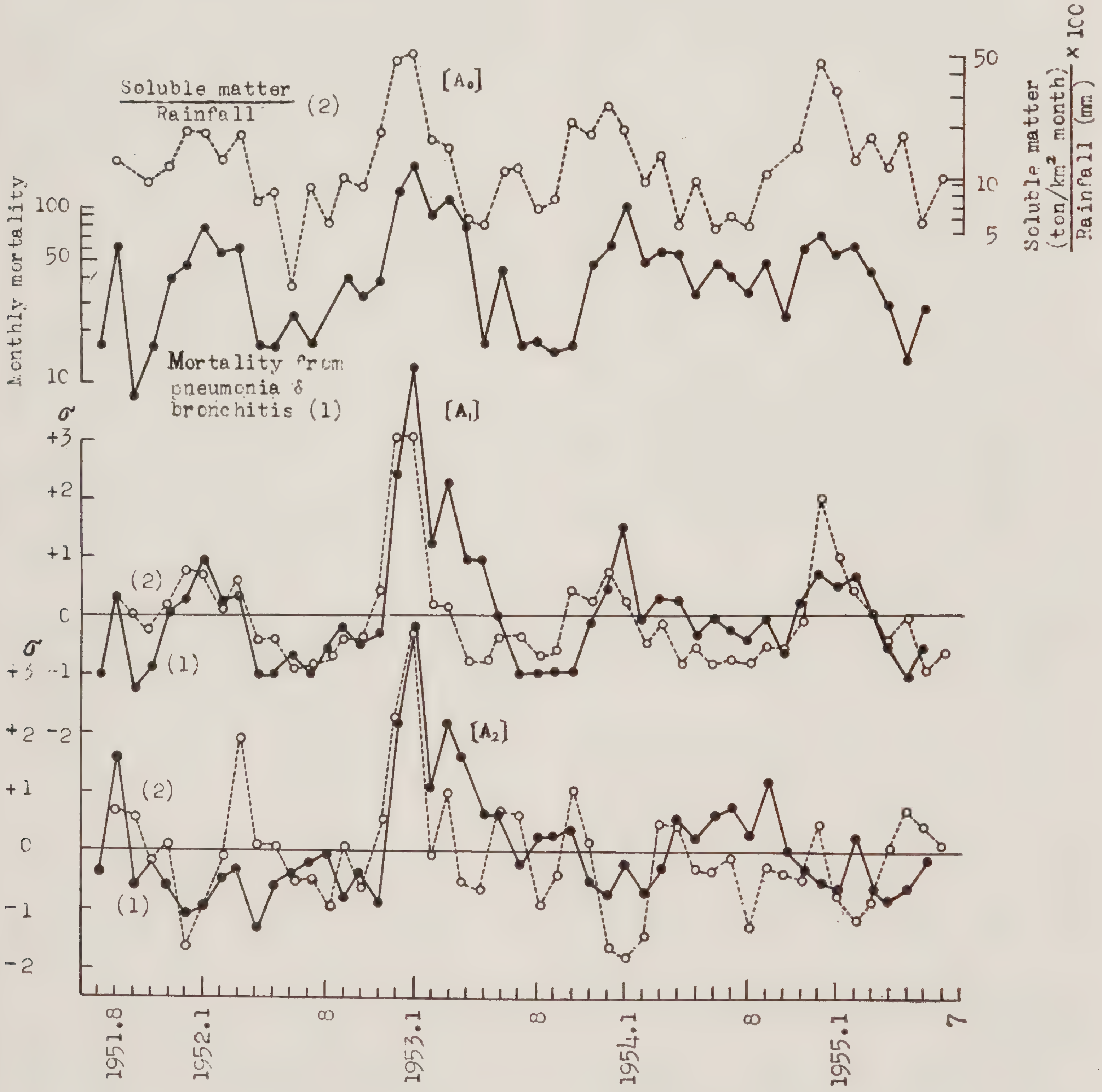

Fig. 3. Relationship between the variations of monthly mortality from pneumonia, bronchitis and deposited atmospheric impurity, in Ube city, analyzed to the following three time series: (A_0) Original monthly time series; (A_1) Time series that eliminates Trend from original monthly time series; (A_2) Time series that eliminates Trend and Seasonal Variation from original monthly time series. Note 1: Fig. 5 is figured mortality which is to occur a month later. 2. Monthly mortality=

$$\frac{\text{Deaths in one month}}{\text{population}} \times \frac{355 \text{ (or } 366)}{\text{Days in month}} \times 100\,000$$

V. 72

OBSERVATIONS ON THE RELATIONS BETWEEN AIR POLLUTION AND PUBLIC HEALTH

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SUMMARY: It is pointed out that the carrying out of efficient preventive methods is hindered by the inability to present a picture of the real and actual dangers deriving from atmospheric pollution. Public Health authorities cannot be expected to adopt expensive measures to deal with pollution unless the necessity can be strictly proved from the health point of view. Research spent to verify the effects of pollution on health will therefore be quite justified. Observations carried out in Great Britain which tend to show a correlation between mortality especially from bronchitis, and air pollution, are not borne out by Italian experience. Researches have led Italian investigators to the conclusion that in the case of lung cancer at least, cigarette smoking, motor traffic fumes, and industrial atmospheres are greater causes than general air pollution. In the light of these results it is felt that it is necessary to examine carefully evidence which seems to suggest a connection between health and air pollution. The paper concludes by suggesting the establishment of an International Centre for the promotion and co-ordination of epidemiological studies of the relationship between atmospheric pollution and public health.

The recent development in research aiming to ascertain the quantity and quality of air pollution in towns may be deemed satisfactory, just as we may consider fairly favourable the situation concerning the availability of preventive means and the interest shown by public opinion.

However, we must say that in many instances the carrying into effect of the most efficient prophylactic measures is decisively hindered by the fact that we are not absolutely in a position to present a picture of the real and actual dangers deriving from atmospheric pollution, and which is not based on simple assumptions or references to exceptional events (smog). On the other hand we must admit that we could never pretend that public health bodies should adopt expensive measures unless the necessity of such adoption be strictly proved from the sanitary point of view. That is to say, that time and money spent in ascertaining and sampling atmospheric pollution will be quite justified when we are in a position to give a " sanitary interpretation " to the mass of figures which we are and shall be collecting.

The assumptions so far put forward in regard to the possible damage due to atmospheric pollution concern, as is well known, almost exclusively diseases of the respiratory organs, among these—in a particular way—bronchitis and cancer of the lungs.

With regard to bronchitis there would appear, from some observations carried out in Great Britain, to exist a correlation between mortality and atmospheric pollution intensity. Such observations, however, could not be confirmed by similar research in Italy, where regions and areas in the same city (Genoa) having a greater density of the various sources of atmospheric pollution were not those in which there was a higher rate of mortality from bronchitis.

We cannot help thinking that there must be some other factors which account for it in a marked if not preponderant measure. This, of course, does not permit us to exculpate atmospheric pollution but makes it difficult to determine its actual function.

A clear example as to how an adequate extension of research may give new dimensions to the impressions obtained from unilateral observations is established by the ratio existing between atmospheric pollution and cancer of the lungs. As in the case of bronchitis, and we would say with greater evidence, the higher mortality ascertained in urban districts and the "total " correlation noticeable, roughly, between mortality and atmospheric pollution of various origins (industrialization, motor traffic, domestic heating plants) throws the blame on atmospheric pollution in determining the increase of mortality from lung cancer.

The most recent and thorough researches we have carried out in Italy during the course of which we have taken simultaneously into account all those factors which could logically be suspected (and not one single factor at a time) have supplied a picture of the situation quite different from that which many people (smokers in the lead) like to imagine.

In fact, we carried out researches on mortality from malignant tumours of the lungs in Genoa as well as in the whole of Italy, referred to the consumption of the various blends of tobacco, to the presence of the various sources of air pollution, to professional activities, to the age of the population, and to other reference indices.

During the course of this research we applied methods of statistical elaboration (correlation and partial regression, etc.) suitable to put to the fore true correlations and simply automatic correlations, and to check the meanings of the differences so found.

The results have led us to the conclusions that so far, in Italy, and particularly in Genoa, the exogenous factors which might have exercised an influence on mortality from malignant tumours of the lungs may be considered as follows:

(a) Firstly cigarettes smoking to which we might attribute about 75–80 per cent of the cases;

(b) Motor traffic which, it is thought, might be blamed for about 10–15 per cent of the cases as a consequence of the heavier mortality among drivers;

(c) Occupational hazards connected with some industrial activities, which would be—besides the well known particular cases of some miners (Schneeberg, Joachimstal) and in processing plants for chromium compounds—those engaged in metallurgical work in general (smelters, blacksmiths, welders, turners, coppersmiths, braziers, etc.) with particular reference to " painters."

On the whole, such professional hazards might account for, in Genoa as also in the whole of Italy, 10 per cent of the cases.

It is of course superfluous to lay stress on the fact that such conclusions in addition to being subject to the usual reservations of a general character, have a strictly local value, limited to the areas under consideration.

It is evident, in fact, that even admitting the validity of our general assumptions one can foresee different situations, from area to area, in relation to the distribution of the three main factors in question, i.e.: cigarette smoking, intensity of motor traffic and the number of workers in factories exposed to occupational hazards.

On the strength of such conclusions one can easily explain the epidemiological trend of the frequency of malignant tumours of the lungs, the global connections with urbanization and industrial and economic development. It follows, however, that the atmospheric pollution of the open air, especially when connected with domestic heating plants and factories—which are the most marked and the causes of the highest values recorded with our pollution measuring apparatus—are in effect factors less worthy of consideration.

An adequate amplification of the factors under consideration has placed in its proper light some correlations which were wholly apparent and has supplied a description nearer to the real situation existing in regard to cancer of the lungs.

Likewise for other diseases of the respiratory organs it is necessary to be prepared to consider all the most important factors in question; this should allow clarification of the observations—apparently discordant—so far made and might prove the absence of meaning in correlations apparently worthy of consideration, and might lay stress on some connections which when superficially examined would escape one's attention owing to the overlapping of the influence of other factors.

Briefly, the problem is characterized by the fact that the distribution of atmospheric pollution is, unfortunately, nearly always overlapping the distribution of many other factors connected with urbanization which exercise far from negligible influences on our health (e.g. cigarette smoking).

In the circumstances the only way to clarify the single responsibilities lies in directing research on a scale as vast as possible, with numerous observations and bases of comparison, taking particular care of all the systems of collection and statistical elaboration of data, which should be unified in common agreements so as to permit a better comparison of the observations made in various places and a better interpretation, even on an international basis, of the differences existing between local situations with a view to identifying the responsible factors.

A field which seems to be useful for a detailed study is the scholastic sector, which it is important to consider for obvious reasons.

In Genoa we have started to check the attendances and absences, due to various causes, with a particular reference to respiratory diseases, in all schools in the several municipal districts. The first observations have shown that one cannot expect to find easily rough differences attributable to various degrees of air pollution. We are of the opinion that a study of this kind made with a survey and elaborate technique made, uniform by those countries possessing an efficient school vigilance service, might provide some precious data, which would be out of reach of a few isolated researchers.

Accepting the premise that the most important present problem to be solved in the field of studies on atmospheric pollution is to make clear the relation with public health, and admitting also that this can be achieved above all through epidemiological researches, well co-ordinated and sufficiently extensive; having ascertained the insufficiency of isolated observations so far realized in various countries, and taking the hint from the fact that, as regards the sampling of atmospheric pollution we have by now reached a fair standardization and international co-operation in the methods of determination; we propose to consider the usefulness of establishing an International Centre for the promotion and co-ordination of epidemiological studies on the relation existing between atmospheric pollution and public health.

V. 73

CARCINOGENESIS BY ATMOSPHERIC POLLUTANTS

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SUMMARY: The paper reviews recent studies, reports and findings on the relationship between lung cancer, cigarette smoking and air pollution, and discusses the carcinogenic hazards from radium and strontium-90 fallout from atomic bombs. Rough estimates suggest that the death rate from osteogenic sarcoma caused by strontium-90 fallout to date will be relatively minor compared with the present death rate from lung cancer ascribed to conventional air pollution in cities.

Highly carcinogenic substances are present both in conventional atmospheric pollutants such as coal smoke, and in radioactive fallout from atomic bomb explosions. These substances occur in such low concentrations that they might be called " harmless," except that a large part of the human race has been or will be exposed to these agents throughout their entire life-span. The problem of quantifying the increased statistical risks of developing cancer due to life-long exposure to these low-level carcinogens is both important and difficult.

By far the easier problem is posed by conventional atmospheric pollution. At present, the products of incomplete combustion of fuels such as coal, fuel oil, diesel oil and gasoline are suspect. Soot resulting from incomplete combustion of these fuels contains polycyclic hydrocarbons, of which 3, 4- benzpyrene is a typical member, and several of these are potent carcinogens when tested in animals. With the possible exception of arsenic, it is generally doubted that industrial respiratory carcinogens other than those derived solely from fuels have a significant effect on any large segment of the general public (Kotin, *Cancer Res.*, **16,** 375, 1956).

Cancer of the lung is the only common form of cancer which is rapidly increasing in most countries in the world. Thus, the male death-rate from lung cancer more than doubled in England during the 10 years from 1944 to 1954. Population studies have proved beyond reasonable doubt that cigarette smoking is the main cause for this increase (Anon, *Chem. & Eng. News*, p. 27, April 8, 1957; Reif, *Science*, **128,** 1512, 1958). With smokers, the powerful carcinogenic effect of cigarette smoke tends to overshadow the effect of atmospheric pollution. Thus, the effect of atmospheric pollution is most clearly revealed with nonsmokers.

Stocks and Campbell (*B.M.J.*, **2,** 923, 1955) have estimated the age-standardized death rate from lung cancer for nonsmokers residing in certain British rural districts as about 11 per 100,000. For nonsmokers living in Liverpool, this rate was higher by 100 per 100,000. The data of Hammond and Horn (*J.A.M.A.*, **166,** 1294, 1958) indicate that the lung cancer rate for nonsmokers in rural areas in the U.S.A. is 2 to 3 per 100,000, compared to about 20 per 100,000 for nonsmokers living in cities. In both countries, nonsmokers had a lung cancer death rate approximately nine times higher if living in cities rather than in rural areas. However, the rate ascribed to atmospheric pollution was five times higher in Liverpool than in an average American city. When the entire population (including smokers) was considered, atmospheric pollution was responsible for about 40 per cent of the lung cancer deaths in Liverpool, against 20 per cent or less in American cities.

The overall death rates from lung cancer in the age group of 50–69 years in England and Wales are 233 per 100,000, compared to 115 per 100,000 in the U.S.A. (Hammond, *B.M.J.*, **2,** 649, 1958). These figures fall into line on the basis of the greatly increased atmospheric pollution in British cities, and on the basis that the British smoke cigarettes down to shorter butt lengths than do Americans. Thus Hammond (*loc. cit.*) found the average butt length 31 mm in the U.S.A., compared to 20 mm in a typically European country such as the Netherlands.

It must be stressed that the lung cancer death rates in the nonsmoker groups mentioned above are based on small numbers—20 deaths in 63,000 nonsmokers—since nonsmokers are a minority and lung cancer in rural nonsmokers is rare. Therefore, conclusions based on these figures serve only as a rough indication of what future studies may reveal.

In the above studies, the effects of atmospheric pollution and of smoking were additive. This was expected, since both types of smoke contain essentially the same carcinogens. Of high importance is the finding of Doll *et al.* (*B.J. Cancer* **11,** 43, 1957) later confirmed by Stocks and Campbell (*loc. cit.*), that the incidence of lung cancer is directly proportional to the number of cigarettes smoked. There is an indication that this proportionality also applies to the average 3,4-benzpyrene content of the atmosphere (Stocks and Campbell, *loc. cit.*) and to the average smoke concentration (Stocks, *B.M.J.*, **1,** 74, 1959).

The major carcinogenic hazard from atomic bomb explosions is strontium-90, although other fission products are known to be relevant and still others are yet to be identified. Recently, Schulert has drawn attention to long-lived plutonium-239 as potentially dangerous (Abstr. Boston Meetg., Am. Chem. Soc., p. 36C, 1959). Experimental work indicates that measurable traces of this extraordinarily potent carcinogen are deposited in the human lung by inhalation of contaiminated dust.

Strontium-90 constitutes 5 per cent of the radioactive isotopes produced in fission explosions and only loses one half its radioactivity in 28 years. Following an explosion, strontium-90 particles are dispersed diffusely in the earth's upper atmosphere and gradually fall out on to plants and soil. They are incorporated into plants and foods, and absorbed into the human body mainly from calcium-rich foods such as milk. The human body uses strontium-90 somewhat interchangeably with calcium for building bone.

No information is presently available on the biological effect of strontium-90 in man. Thus, all statements on the carcinogenic risks of strontium-90 fallout are estimates. Here, two ways of assessing the hazard are described: both depend on previous human experience with exposure to radium, and both link this experience to strontium-90 by experiments with mice, which compare the carcinogenic action (chiefly bone tumor formation) of these two radioactive substances.

Both methods require the controversial assumption that a direct proportionality exists between dose and carcinogenic effect. Unfortunately, even experiments with millions of mice may fail to resolve this controversy. Man is the most convenient and certainly the relevant experimental animal. Our current self-experimentation with pleasantly-flavoured carcinogens in the form of cigarette smoke have this value: they indicate that proportionality between dose and carcinogenesis can apply in a large human population exposed continually to a low-level carcinogen during adult life.

From the medical history of people who had eaten or been injected with radium, Hasterlik (" Peaceful Uses of Atomic Energy," vol. 2, Un. Nat., N.Y., p. 149, 1956) estimated that 100 millimicrocurie radium carried in a person's bone causes one death from bone cancer in 200 people. The present author has estimated this risk independently and agrees with this figure within 20 per cent. From animal experiments, the International Commission on Radiological Protection (*Brit. J. Radiol.*, Suppl. No. 6, 1955) estimated the toxic doses producing the same carcinogenic effect were in the ratio of 1:10 for radium compared to strontium-90; more recent data by Finkel (Acta U.I.C.C. **15,** 99, 1959) give a ratio of 1:30 at the optimal tumor dose, but 1:6 if the number of tumors produced at this dose is considered. Retaining the Commission's toxic dose ratio of 1:10, Hasterlik's estimate indicates that 1,000 millimicrocurie strontium-90 would cause one case of bone cancer in the lifetime (65 years) of 200 people, or one case per 65 × 200 people per year (Atomic Scientists Assoc., in " The Nature of Radioactive Fallout and its Effects on Man," U.S. Gvt. Printing Office, part 2, p. 1669, 1957). Simple arithmetic indicates that an average bone burden of 100 millimicrocurie strontium-90 would increase the present U.S. rate of osteogenic sarcoma by eight cases per million people per year, an increase of 40 per cent. If we assume a future U.S. equilibrium burden of six millimicrocurie strontium-90 from bombs already exploded, we can expect eventually an increased incidence of one case per two million per year.

The error in the above estimate may well be as high as 10-fold. For with radium, a few relatively high doses were given to a few hundred adults; with strontium-90, a fairly uniform continuous low dosage is being taken currently by the billions of people of all ages and races that comprise humanity. The extrapolation of toxic dose ratios from acute mouse experiments to semi-permanent exposure in man is also tenuous.

A second method of estimating the potential carcinogenicity of strontium-90 is to ascribe 15 per cent of the natural incidence of osteogenic sarcoma to the background radiation, based on analogy with Lewis' estimate (*Science*, **125,** 965, 1957), for leukemia. Since one-third of the natural background radiation of human bone is due to a natural radium content of about 0·1 millimicrocurie (Spiers, *Brit. J. Radiol.*, **29,** 409, 1956), 5 per cent of the natural incidence of osteogenic sarcoma or one case per million per year is ascribed to this radium content of bone. Substituting the toxic dose ratio of 1:10 from animal experiments, one additional case of osteogenic sarcoma per million people per year is estimated to be due to a skeletal content of one millimicrocurie strontium-90.

This estimate is 13 times higher than the first estimate and is also highly questionable. Here the conditions for radium exposure are close to those relevant for strontium-90. However, the assumption that one case of osteogenic sarcoma in 20 is due to the natural skeletal content of radium may be reasonable, but has no basis on fact.

In conclusion, these rough estimates suggest that the death-rate from osteogenic sarcoma, caused by strontium-90 fallout from atomic bombs exploded up to May 1959, will be relatively minor compared to the present death-rate from lung cancer ascribed to conventional atmospheric pollution in cities. However, a nuclear war could radically reverse this position overnight. The sobering certainty remains that any present estimate of the possible future carcinogenic effects of fallout is at best only a rough guess.

V. 74

PHOTOCHEMICAL AEROSOL FORMATION IN SULPHUR DIOXIDE-HYDROCARBON SYSTEMS

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SUMMARY: The research described in this paper is part of a programme being conducted by Stanford Research Institute under the sponsorship of the Air Pollution Foundation. This programme is aimed at elucidating the chemistry of photo-oxidation, the mechanism of aerosol formation, and the properties of aerosols so produced. The work reported here covers a preliminary study of the important parameters governing aerosol formation and a cursory survey of the potential of hydrocarbon types for aerosol formation. The layout and method of use of the apparatus for irradiation are described. It is concluded that sulphur dioxide plays a large part in aerosol formation in urban atmospheres containing hydrocarbons and nitrogen oxides. The observed high sulphate content and abnormally low sulphur dioxide content found in the air of the Los Angeles Basin are easily explained by the result presented in this paper.

Introduction

Experimental efforts in the study of the smog problem have been concentrated on elucidation of the process of photo-oxidation occurring in urban atmospheres containing traces of hydrocarbon and nitrogen oxides. Relatively little effort has been devoted to the study of aerosol formation, pending the development of some understanding of the chemistry involved. The formation of aerosols[1] and a possibly important role of sulphur dioxide in aerosol formation have been demonstrated in irradiated dilute mixtures of auto exhaust and air.[2] Haagen-Smit and co-workers[3] have demonstrated aerosol formation from irradiated mixtures of air and concentrations of hydrocarbons and oxides of nitrogen around a few parts per million by volume. In this work the cyclo-olefins were found to be the most potent aerosol formers.

The present study is part of a programme being conducted by Stanford Research Institute under the sponsorship of the Air Pollution Foundation. This programme is aimed at elucidating the chemistry of photo-oxidation, the mechanism of aerosol formation, and the properties of aerosols so produced. The work reported here covers a preliminary study of the important parameters governing aerosol formation and a cursory survey of the potential of hydrocarbon types for aerosol formation.

Experimental Apparatus

The photo-oxidations were carried out in a stirred-flow reactor consisting of a 50-litre round bottom Pyrex flask fitted with an all-glass paddle-wheel recirculating blower (30 l.p.m.) to draw air from the bottom of the flask and discharge it through the flask neck. Air for the reaction mixture was drawn by means of a diaphragm pump from a manifold carrying purified air for a large irradiation chamber.[4] The air stream was forced through a bed of activated alumina (Laboratory Lectrodryer) and split into two metered streams. One stream was passed countercurrent to a dropwise stream of water through a bed of glass Raschig rings. Near-saturation of this air stream was achieved by adjusting the electric current through glass heating tape wrapped around the downstream end of the bed until the temperature at the upstream end was approximately equal to the ambient. This saturated stream was then mixed with the other metered stream (thus obtaining an air stream of known relative humidity), preheated and passed through a 5 in. by 1·5 in. bed of platinized alumina at 600°C, cooled in copper tubing, metered, and discharged into a mixer.

The other components of the reaction mixture were fed to the mixer through glass capillary tubing and sensitive float-type flow meters from pressurized stainless steel tanks containing reactant gases greatly diluted with prepurified nitrogen. The mixer consisted of a 125 m.l. flask sealed on to a float-type flow meter. The main air stream was entered tangentially to cause a swirling motion in the flask over the capillary jets through which all of the minor components, except nitric oxide, entered the mixer. Dilute nitric oxide was introduced through a capillary jet in the throat of the flow meter to shorten its mixing time and thus to avoid its undue oxidation to nitrogen dioxide. The major mixing action for this component took place in the annulus around the glass float of the flow meter. The stream from the mixer then passed through an aerosol filter consisting of three pads of fired MSA 1106 glass mat[5] and into the reactor at the throat of the recirculating blower.

The effluent stream from the reactor was taken from the recirculating stream just after it came from the bottom of the reactor. The effluent stream was then fed to various instruments, including an aerosol counter photometer[6] for measurement of light-scattering properties, a nuclei counter of the Aitken type[7] and a continuous analyzer based on colorimetric method for analysis of sulphur dioxide.[8] Occasionally, a similar type of recorder was used for analysis of nitrogen.[9]

Light-scattering measurements were always carried out using diluting and sheath air streams of essentially the same humidity as the reactor effluent to avoid hydration or dehydration of the aerosol particles. This was done by using a closed-circuit counter photometer flow control system[10] where leakage was held to a negligible rate. The system was vented at a known flow rate so that samples could be taken at a known rate. Before each experiment the control system was equilibrated by allowing air of controlled humidity to flow from the reactor through the system at several litres per minute for about an hour. This same relative humidity was then used in the subsequent experiment.

Irradiation was by means of four General Electric H400–E1 medium-pressure mercury arc lamps placed symmetrically about the 50-litre reactor. The radiation was filtered by the Pyrex lamp envelopes and the walls of the reactor. The intensity within the flask was augmented by enclosing the flask with aluminium foil having four windows 6 in. by 6 in. The resulting intensity distribution within the reactor had been previously studied and found relatively uniform.[11]

Previously, an intensity of $9{\cdot}2\times10^{15}$ quanta sec^{-1} cm^{2} had been measured within the reactor with water-cooled filters (Corning specification 7-60) in the light path to isolate the 366μ line.[12] Using General Electric Company's data for the spectral power distribution of H400–E1 lamps and the transmittance of Corning filters plus the transmittance of water made it possible to obtain a figure for the geometric efficiency of the irradiation system of $2{\cdot}78\times10^{-5}$ cm^{-2}. Because of the approximate nature of some of the basic data it was not considered worth while to take into full account in the calculation the reflection phenomena at interfaces of the composite filter. However, in the absence of actual measurement of spectral distribution within the reactor, this calculated efficiency yields approximate values of the spectral distribution within the reactor, using G.E.'s spectral power distribution data as a base of calculation and the expression $P\lambda \times \lambda \times 5{\cdot}04 \times 10^{16} \times 4 \times 2{\cdot}78 \times 10^{-5} \times T\lambda$ quanta sec^{-1} cm^{-2} $(10\mu)^{-1}$ where $P\lambda$=power spectral distribution in watts, $x=(10\mu)^{-1}$, $T\lambda$=reactor wall transmittance, and λ=wavelength in millimicrons. The result is shown in Fig. 1 and is compared with Leighton and Perkins's values of the corresponding quantities for sunlight under representative conditions at a solar zenith angle of 0°.[13] The result may be expected to be least accurate near 300μ.

Materials

Air purified in the above-described purification train was examined by means of a long-path infra-red spectrophotometer and analyzed by a NO-NO_2 recording colorimeter. The pure air contained less carbon dioxide than did the ambient air (probably because of adsorption by the activated alumina) and less than two parts per hundred million of nitrogen oxides. No significant amount of impurities, such as hydrocarbons, were detected—that is, less than 0·2 p.p.m. were present. Blank runs using a SO_2 colorimeter recorder did not indicate the presence of sulphur dioxide—that is, less than 0·01 p.p.m. were present. Sulphur dioxide is probably removed by adsorption in the drying tower and by oxidation over the hot platinum catalyst.

The nitric oxide used was Matheson C.P. grade. The hydrocarbons were mainly Phillips Pure Grade or Matheson C.P. grade. In some instances, particularly in the case of aromatic hydrocarbons, C.P. grades of other manufactures were used. Ethyl benzene was taken from a lot which had been purified by distillation in this laboratory. The 1-butyne was taken from an A.P.I. standard sample ampoule. The prepurified dry nitrogen used to pressurize and dilute the reactants was obtained from Air Reduction Co.

Reactants were stored in stainless steel tanks which had been washed thoroughly with organic solvents, dilute acid, detergent, and distilled water and then had been steamed out. After steaming, the tanks were baked at ca. 150°C, fitted with plugs and valves, and again baked under evacuation, at ca. 10^{-5} mm. The latter step was repeated before each refilling of the tanks.

The tanks were filled by means of an all-metal vacuum manifold coupled to a conventional oil diffusion pump. After evacuation, the system was filled with the desired gas to a predetermined static pressure. Prepurified nitrogen was then bled into the system from a high-pressure cylinder until the desired 100 p.s.i.g. final pressure was attained. The necessity of accurately measuring the rate of flow into the reactor usually imposed the condition that these bleeder tanks contain reactants at a concentration around 100 p.p.m. by volume.

Liquid reagents were freed of dissolved gases by several repetitions of the freeze-pump-warm technique before the vapour was allowed to enter the metal vacuum system.

Experimental Data: Photo-oxidation of Sulphur Dioxide in Air of 50 per cent Relative Humidity

A rough estimate of the small decrease of sulphur dioxide concentration due to photo-oxidation was obtained in several experiments in which only sulphur dioxide and water vapour were present These data are given in Table I. The absorption rate of sulphur dioxide in the reactor was estimated to be 0·013 min^{-1} calculated from the data of Fig. 1 and the absorption coefficients found by Hall and Blacet.[14] Combination of the average rate of photo-oxidation with this absorption rate gave a quantum yield for sulphur dioxide consumption of about 0·3.

This rate and quantum yield were based on the assumption that the secondary photochemical processes are such that the rate is directly proportional to the sulphur dioxide concentration found by Hall and Blacet[15] under considerably different conditions. These authors found a considerably smaller quantum yield of 0.036 at 3130A and 25°C (dry system, $P/SO_2 = 12{\cdot}7$ mm, $P/O_2 = 10{\cdot}6$). The sources of the difference are probably the higher total pressure, the much lower concentrations, and the presence of water vapour, combined with probable large errors in estimating absorption rates and the rate of photo-oxidation in the Institute's reactor. If the same quantum yield of 0·3 is assumed for sunlight, then a photo-oxidation rate of 0·004 min^{-1} is obtained for the spectral distribution in the lower atmosphere shown in Fig. 1. This is in sharp contrast with the rate of ca. 2×10^{-5} min^{-1} experimentally found for sunlight by Gerhard and Johnstone.[16] One factor probably contributing to this lack of agreement is the extreme variability of solar intensity in the region of effective sulphur dioxide absorption, 300–340μ.

Data on light scattering from the reactor effluent from photolyzing mixtures or sulphur dioxide and pure air of 50 per cent relative humidity are summarized in Fig. 2. The ordinate represents the amount of light scattered, from 2 μl. of aerosol, corrected for air scattering, divided by the amount scattered by an equal volume of air under the conditions prevailing in the counter photometer cell.[17] The abcissa represents the amount of sulphur dioxide photo-oxidized to form the aerosol, estimated by use of the experimentally determined $4{\cdot}5 \times 10^{-3}$ min^{-1} rate. These data are given in detail in Table II.

The shape of the curve in Fig. 2 is probably determined by the variation in response of the counter

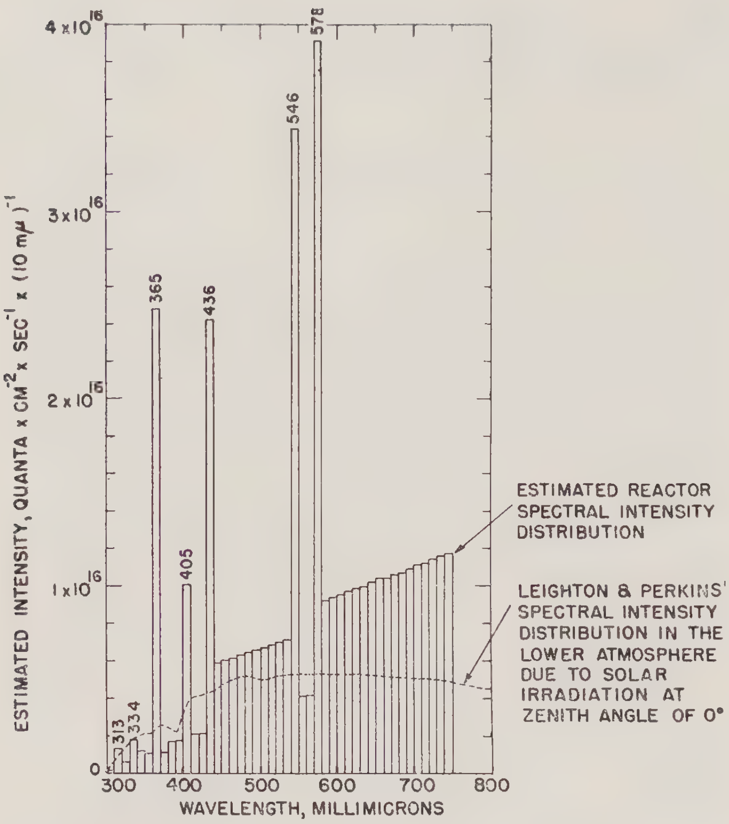
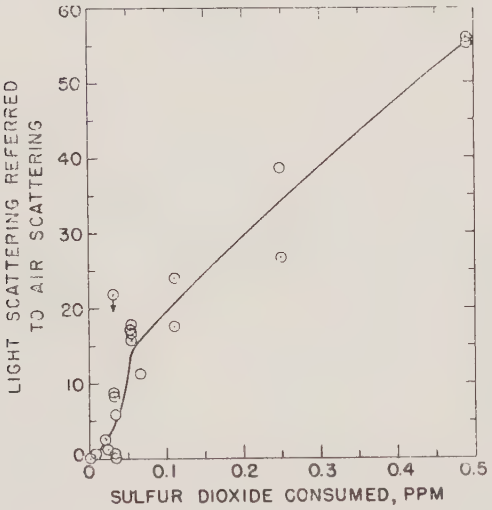


FIGURE 1

ESTIMATED SPECTRAL INTENSITIES WITHIN THE REACTOR AND IN SUNLIGHT



NOTE ♀ MEANS "LESS THAN"

FIGURE 2

LIGHT SCATTERING AS A FUNCTION OF THE AMOUNT OF SULFUR DIOXIDE PHOTOOXIDIZED IN 50% R.H. AIR

photometer with average particle size. For sulphur dioxide consumptions greater than about 0·05 p.p.m., the greater amount of aerosol mass is probably contained in particles large enough to give a response approximately proportional to the square of the diameter.[18] In fact, a plot of scattering versus the 2/3 power of sulphur dioxide consumed is not inconsistent with the hypothesis that approximately the same number of particles of sizes greater than ca. $0{\cdot}2\mu$[19] are produced when the consumption exceeds 0·05 p.p.m. Apparently, when the consumption is less than this, the diameters lie in the transition region where scattering is going from a "square law" response to a sixth power response. In addition, the particle concentration may be rapidly varying in this region.

The importance to air pollution of photo-oxidation of minute amounts of sulphur dioxide to sulphuric acid aerosol can be brought out by a simple calculation which shows that the complete conversion of 0·05 p.p.m. of sulphur dioxide to aerosol at 50 per cent relative humidity will result in a mass loading of ca. $460\mu g$ m^3 of ca. 43 per cent solution of sulphuric acid. A loading of this magnitude can lead to a significant reduction of visibility, as supported by the measured light scattering shown in Fig. 2.

The size distribution of particles above the counting threshold of the counter photometer are shown in Fig. 3 for three of the higher influent concentrations of sulphur dioxide. The size scale is in terms of polystyrene spheres used to calibrate the counter. It is obvious that a considerable number of optically significant particles were present and that the number increased with increasing amounts of sulphur dioxide consumed.

A separate experiment was carried out in which both light-scattering concentration and condensation nuclei (for water) concentration were followed as a function of time after the light shutters were opened. The result is shown in Fig. 4. A great number of nuclei appeared immediately and then decayed to an intermediate value while the light scattering increased steadily. The steady-state consumption estimated for this experiment was 0·02 p.p.m. which lies in the transition region of Fig. 2. It is evident that a great many particles of very low light-scattering ability—that is, very small diameter—were present. Combination of the estimated sulphur dioxide consumption with the nuclei count indicates a sulphuric acid content of $1{\cdot}24 \times 10^{-15}$ gm per particle. If the particle is assumed to have a density of 1·34 gm./m.l. and to consist of a 44 per cent solution of sulphuric acid in water, then one obtains $<d^3>^{1/3} \simeq 0{\cdot}16\mu$ in which d = particle diameter. Since this value represents the third moment of the size distribution, the first moment is probably much less than this figure. This suggests that the photo-oxidation of very small amounts of sulphur dioxide can supply ample acidic nuclei for either physical or chemical condensation of other materials present in the atmosphere.

Only one experiment in this series was carried out to determine the effect of water vapour on sulphur dioxide photo-oxidation. The data are given in Table III. Unfortunately, no measurements of effluent concentrations were made during this sequence of experiments to observe possible effects on the photo-oxidation rate. The effect on light scattering was striking, as Table III indicates.

Table III
Light-Scattering and Sulphur Dioxide Concentration Data showing Effect of Relative Humidity

(Influent Sulphur Dioxide Concentration, 0·47 p.p.m. Estimated Sulphur Dioxide Consumption, 0·033 p.p.m. Residence Time 17 minutes)

Experiment Number	*Relative Humidity*	*Light Scattering*
6 A-2	50	5·9
6 A-3	0	0·73 and still decreasing)
6 A-4	50	9·0

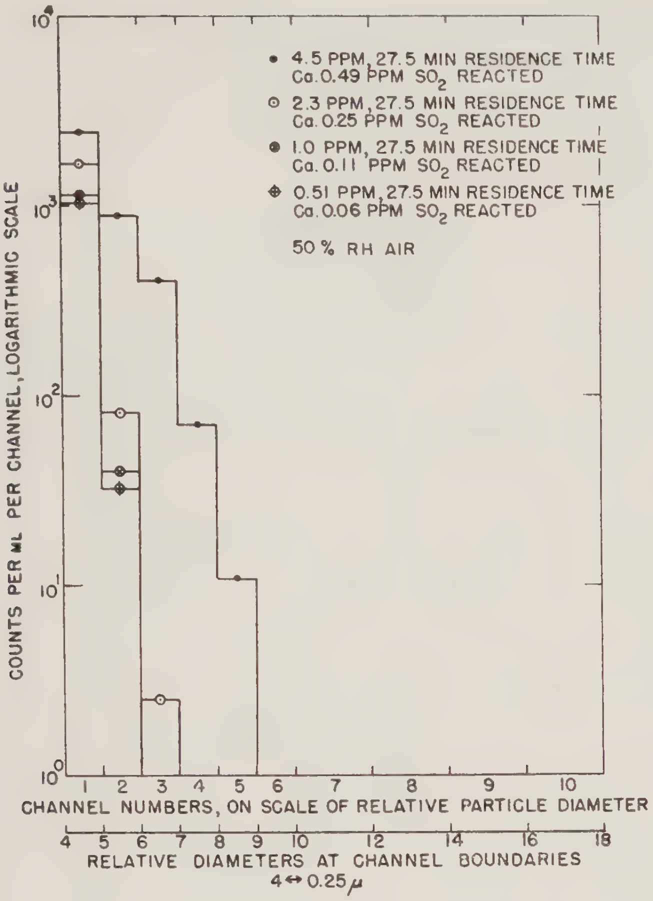


FIGURE 3

PARTICLE SIZE DISTRIBUTIONS OF AEROSOLS PRODUCED BY PHOTOLYZING SULFUR DIOXIDE IN 50% R.H. AIR

Photo-oxidation of Sulphur Dioxide in the Separate Presence of Nitrogen Oxides and Hydrocarbons

Nitrogen Oxides. In one set of experiments nitric oxide (1 p.p.m.) was added to several photo-oxidizing mixtures of SO_2 (0·5 p.p.m.) in 50 per cent R.H. air. There were some indications that the formation of aerosol was hindered by nitric oxide. However, more experimental work will have to be carried out before a definite conclusion can be reached.

The addition of nitrogen dioxide to irradiated mixtures could enhance the oxidation of sulphur dioxide and increase the resultant light scattering because a rate constant of 3×10^{10} λ^2 mole^{-2} sec.$^{-1}$ has been reported for the reaction $SO_2+O+M \rightarrow SO_3+M$. Two experiments (0·14 p.p.m. SO_2, 1 p.p.m. NO_2) gave qualitative indication of an effect of this sort.

Hydrocarbons. A few experiments in which butadiene or pentene-1 (3 p.p.m.) was added to photo-oxidizing sulphur dioxide (0·3 p.p.m.) indicated that the addition of these olefins has a strong suppressive effect on the production of light-scattering aerosol. Possibly the olefins interfere with the chemical reactions and/or with the physical process of aerosol formation.

Enhancement of Aerosol Production and of Sulphur Dioxide Photo-oxidation by Co-photo-oxidation of 2-Methyl 2-Butene with Nitric Oxide

A fairly extensive investigation was made of the enhancement of aerosol production and of sulphur dioxide photo-oxidation by co-photo-oxidation of 2-methyl 2-butene with nitric oxide. These experiments were carried out at 50 per cent relative humidity, keeping the nitric oxide concentration at 1·0 p.p.m. Residence time, sulphur dioxide concentration, and hydrocarbon concentration were varied. The data are given in Table IV, and some cuts through the data are illustrated in Fig. 5. The light scattering predicted for photo-oxidation of sulphur dioxide alone (see Fig. 2) is also shown in Fig. 5 to bring out the marked enhancement resulting from photo-oxidation of the hydrocarbon. It is interesting to note that as much light scattering can be produced with 0·2 to 0·5 p.p.m. of hydrocarbon as with 0·5 to 3 p.p.m., provided that sufficient residence time is allowed for the reaction (same concentration of nitric oxide and sulphur dioxide). Increasing amounts of sulphur dioxide led to increasing light scattering. Perhaps this latter effect will saturate due to interference by sulphur dioxide with the hydrocarbon oxidation, as indicated in the lower right-hand graph in Fig. 5.

The increase in light scattering is most marked at the lower sulphur dioxide concentration. This probably results from the aforementioned transition in

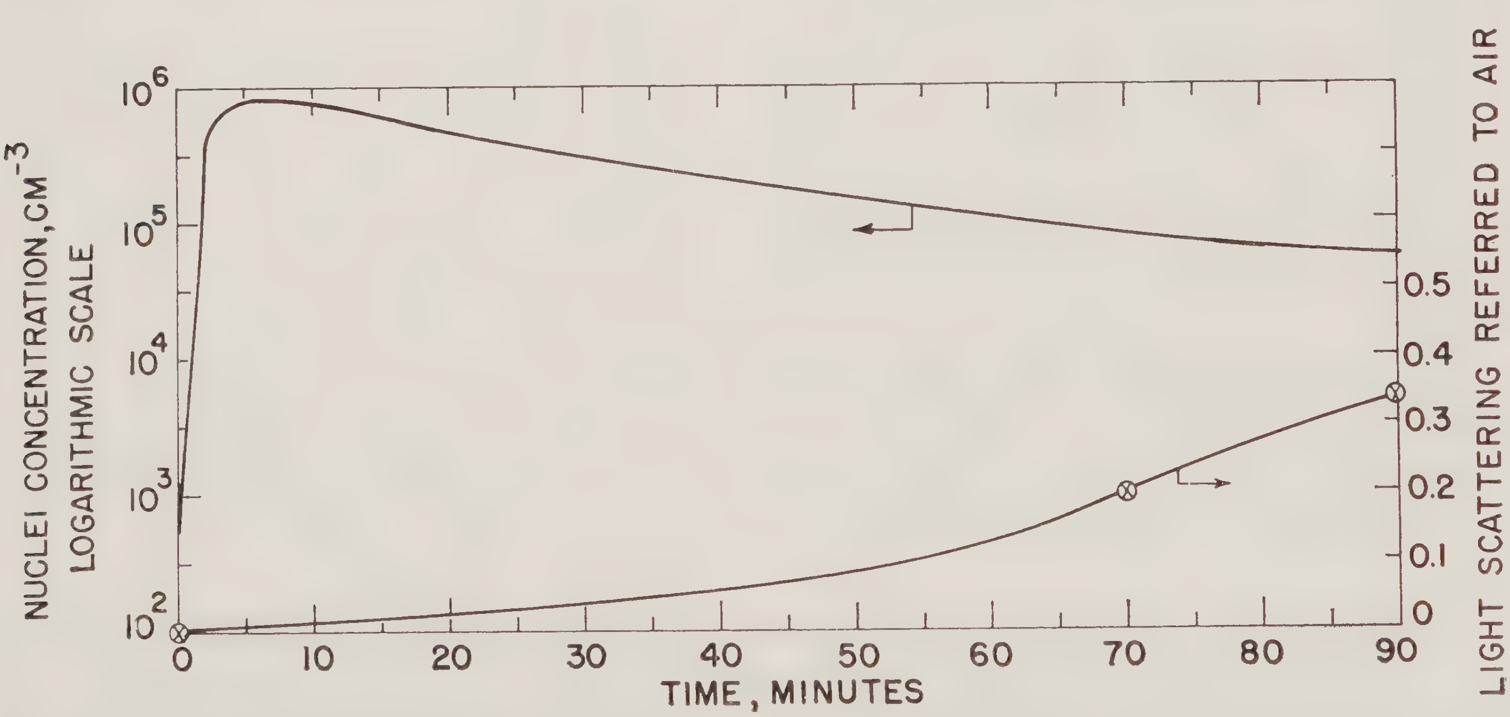


Figure 4. Variation of nuclei and light scattering with time in effluent from photo-oxidized mixture of 0·24 *ppm sulphur dioxide with* 50% *R.H. air (residence time,* 18 *minutes)*

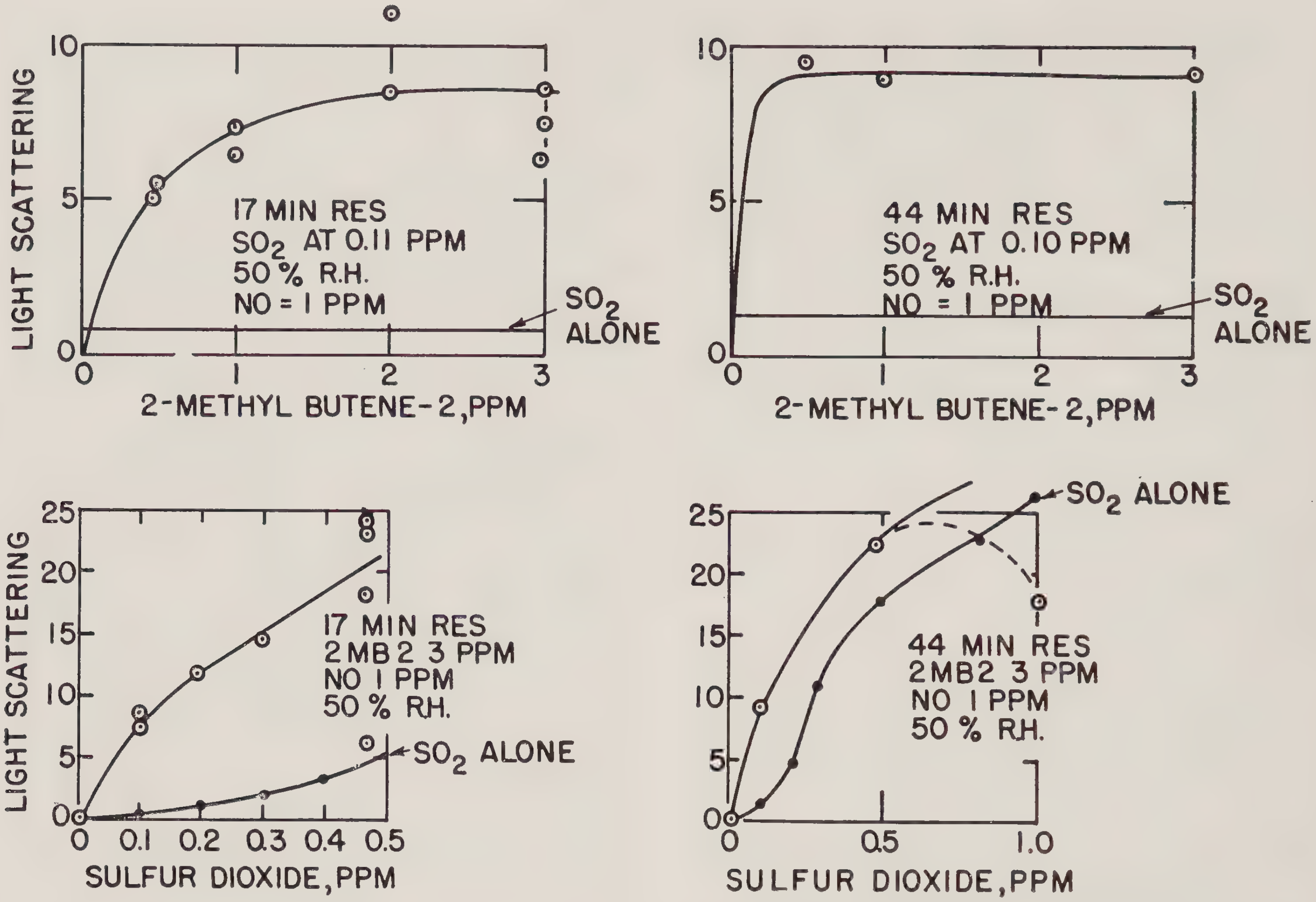


Figure 5. Some cuts through the dimensional space of the data of Table VII compared with light scattering in the absence of hydrocarbon and nitric oxide

photometer response from diameter to the sixth power to the square of the diameter with increasing diameter which renders the method most sensitive to changes at low sulphur dioxide concentrations. However, the changes are good measures of the optical importance of the particles produced.

The particle count tends to parallel the light scattering in those cases where it was measured. The count per size class rose steeply with decreasing particle size in a manner similar to that observed in distributions in irradiated automobile exhaust.[20] The background of larger particles observed in the latter case was absent because the reaction mixture was not filtered.

Experiment No. 8 A-3 (see Table IV) was a deviation from the experimental plan. The humidity was allowed to decrease, and as it decreased the light scattering decreased and the particle size distribution changed, as shown in Fig. 6. It is evident that humidity has a marked effect, which is currently under investigation.

Additional data on those Table IV experiments in which measurements of effluent sulphur dioxide were made are shown in Table V. Values of the rate of sulphur dioxide disappearance are compared with the rate predicted from the SO_2 photo-oxidation rate (Table I) to illustrate that the photo-oxidation of the hydrocarbon accelerates the rate of disappearance of sulphur dioxide.

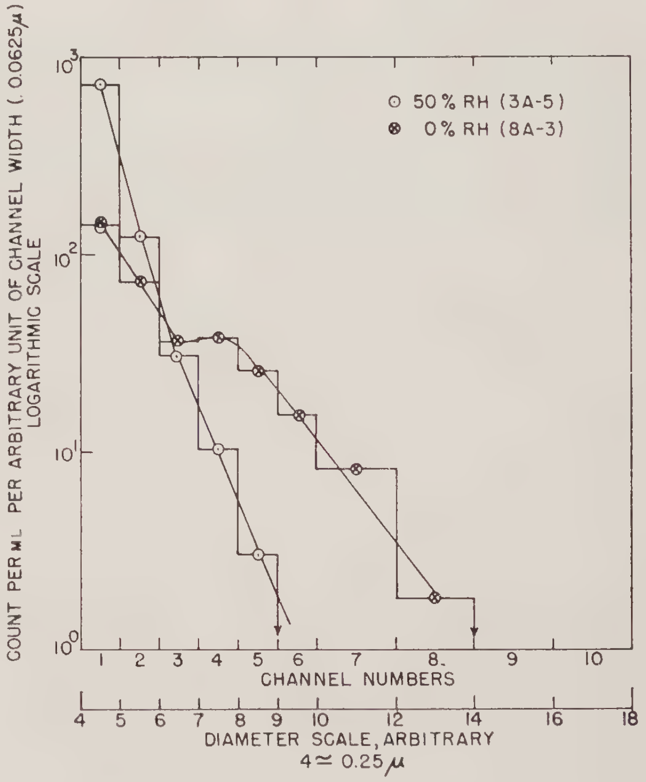


FIGURE 6

CONTRASTS IN COUNTS PER MILLILITER AND PARTICLE SIZE DISTRIBUTION BETWEEN AEROSOLS FORMED BY PHOTOLYSIS OF 3 PPM 2-METHYLBUTENE-2, 1 PPM NITRIC OXIDE, AND 0.5 PPM SULFUR DIOXIDE IN DRY AND IN HUMID AIR

Nuclei in Co-photo-oxidizing Mixtures of Olefin, Nitric Oxide and Sulphur Dioxide

An attempt was made to duplicate in a synthetic system the results obtained with irradiation of auto exhaust from olefin and sulphur-containing fuels.[21] For this purpose a mixture of 3 p.p.m. 2, 3-dimethyl-

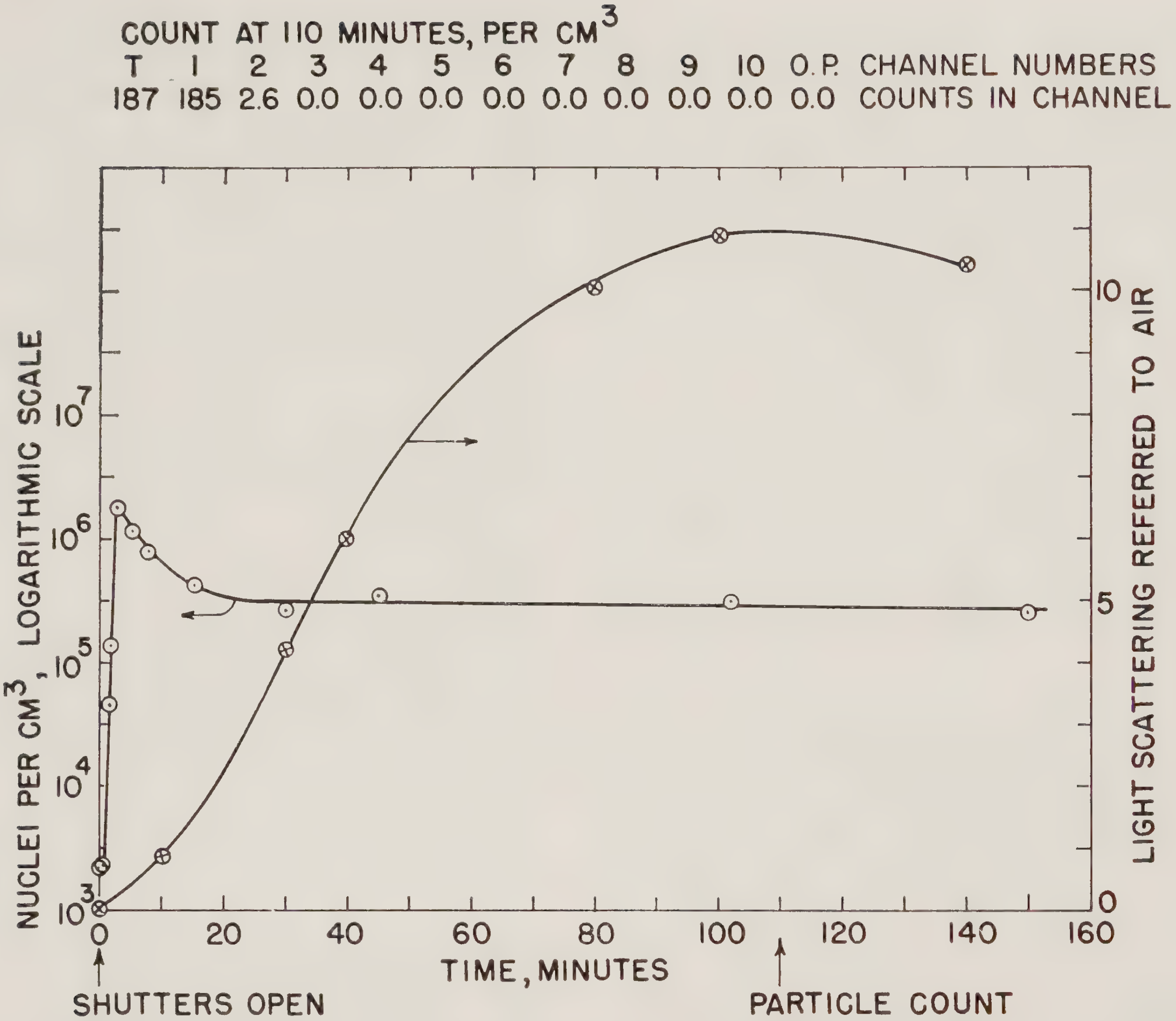


Figure 7. *Nuclei, light-scattering, and particle size distribution data on the effluent from a photolyzing mixture of* 3 *ppm* 2, 3-*dimethylbutene*-2, 1 *ppm nitric oxide, and* 0·1 *ppm sulphur dioxide in* 50% *R.H. air (residence time,* 27·5 *minutes)*

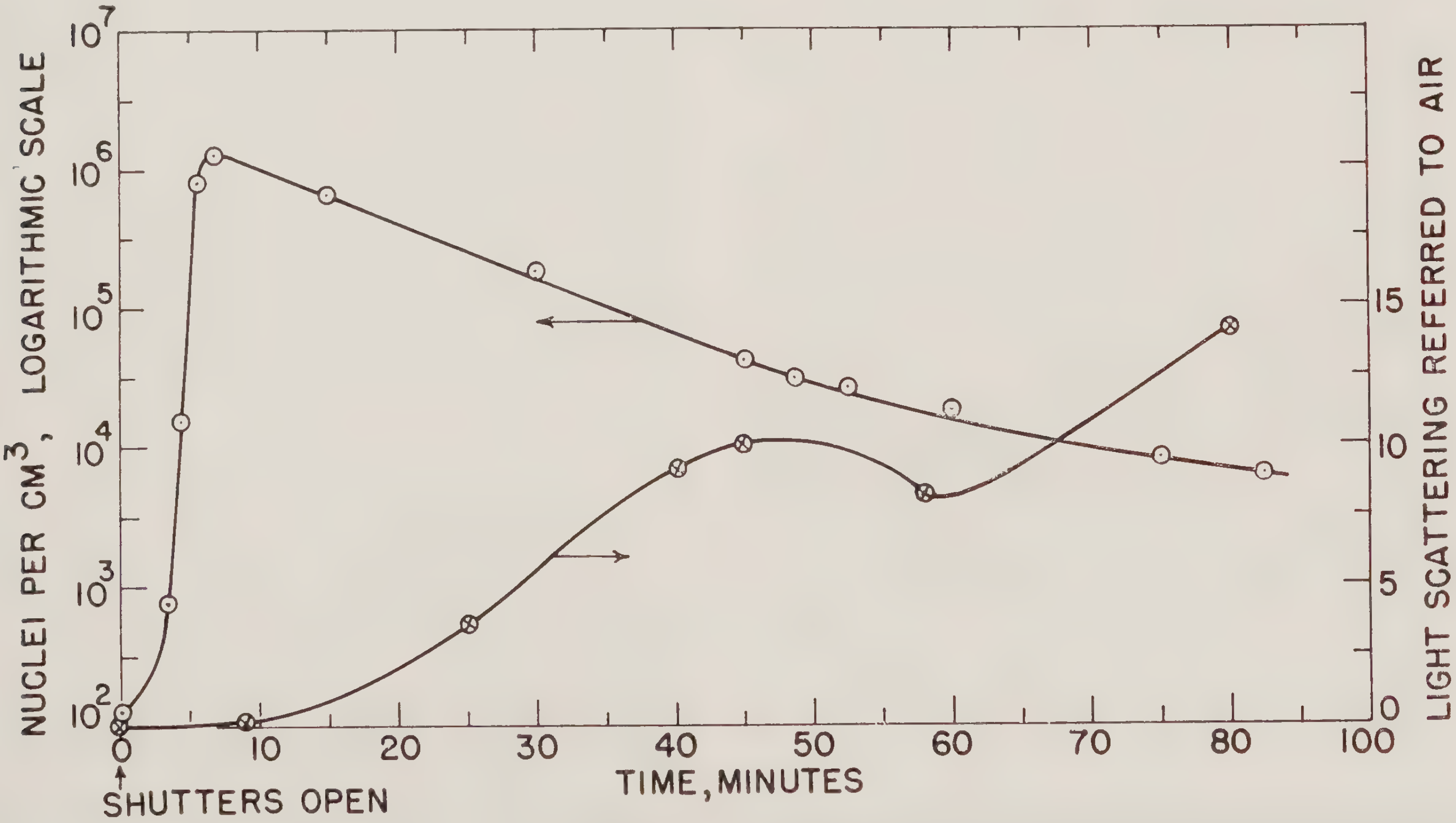


Figure 8. *Nuclei and light-scattering data on the effluent from a photolyzing mixture of* 3 *ppm cyclohexene and* 1 *ppm nitric oxide in* 50% *R.H. air (residence time,* 27·5 *minutes)* butene-2, 1 p.p.m. nitric oxide, and 0·1 p.p.m. sulphur dioxide air was irradiated in the reactor with 50 per cent relative humidity at a residence time of 27 minutes. Light scattering and nuclei in the effluent were each measured as a function of time. The results are shown in Fig. 7 along with the data on a particle count made at steady state. The behaviour of the auto exhaust mixture was qualitatively duplicated. However, the steady-state nuclei concentration was an order of magnitude greater, and the particle count was lower, than for auto exhaust. This may be attributed to the considerable differences in estimated concentration ($\sim$0·5 p.p.m. sulphur dioxide for the auto exhaust) and to qualitative differences in the kind of hydrocarbon present.

Nuclei concentration in the absence of sulphur dioxide was also measured in the case of mixtures of cyclohexene (3 p.p.m.) and nitric oxide (1 p.p.m.). This is the only one of the hydrocarbons tested (see below) which yielded considerable aerosol in the absence of sulphur dioxide. The results are shown in Fig. 8. The considerable number of nuclei for water condensation appear as a transient peak which then decays towards an apparent steady-state level $\sim 10^4$ cm^{-3}.

The Production of Light-Scattering Aerosol from Irradiated Hydrocarbon-Nitric Oxide Mixtures both in the absence and in the presence of Sulphur Dioxide

A cursory survey was made of the efficacy of various hydrocarbon types in producing aerosol under irradiation. Most of the hydrocarbons chosen are representative of the more common types expected to be found in polluted atmospheres. The following fixed conditions were chosen for this study: 3 p.p.m. hydrocarbon, 1 p.p.m. nitric oxide, 50 per cent relative humidity, and 27 minutes residence time. These conditions were deviated from in some experiments but were adhered to in at least one experiment for each hydrocarbon. Influent sulphur dioxide, when used, was generally in the range of 0·03–0·3 p.p.m.

The results obtained in the absence of sulphur dioxide are shown in Table VI. Among the hydrocarbons tested, only branched-chain internal olefins, cyclo-olefins, and diolefins were definitely capable of producing light-scattering material under these conditions. Of these, only the cyclo-olefin—in this case, cyclohexene—showed light-scattering values comparable with those produced by some hydrocarbons in the presence of sulphur dioxide. A very small amount of scattering was shown by 1-pentene, but the amount was so small that the possible effect of impurities in the mixture cannot be disregarded.

The effect on the observed light scattering of adding sulphur dioxide to these same mixtures is shown in Table VII. The olefins tested, including cyclo-olefins and diolefins, were active in accelerating the disappearance of sulphur dioxide. The light scattering from irradiated mixtures of the olefins and diolefins was strongly enhanced by the addition of sulphur dioxide. Ethylene produced an uncertain marginal effect, probably related to its known low rate of photo-oxidation. The addition of sulphur dioxide to the irradiated cyclohexene mixture had no large effect on the already large light scattering, although the upper limit of the range of variation was apparently increased from about 11 to about 23. Some of the saturated hydrocarbon and p-xylene nitric oxide mixtures apparently suppressed the appearance of aerosol completely. There are strong indications that some of these same mixtures may have enhanced rather than suppressed sulphur dioxide disappearance at the same time that no appreciable aerosol was being produced. This points to the presence in these systems of processes other than co-photo-oxidation of sulphur dioxide to sulphuric acid. Methane, 2, 3-dimethyl propane 1-butyne, and benzene-nitric oxide mixtures had no great effect on the photo-oxidation of sulphur dioxide and the associated production of aerosol. Toluene and ethyl benzene may have strengthened the light scattering slightly, but there was no evidence of pronounced acceleration of sulphur dioxide disappearance.

Since all of these experiments were performed under arbitrarily fixed conditions with no or few replications, it is probable that there are conditions under which aerosol can be produced with and without sulphur dioxide in the presence of some of the inactive hydrocarbons. However, the results summarized above do bring out the marked activity of the olefins in this phenomenon.

Discussion

Implications for Air Pollution

It is apparent that sulphur dioxide does play a large role in aerosol formation in urban atmospheres containing hydrocarbons and nitrogen oxides. The observed high sulphate content and abnormally low sulphur dioxide content found in the air of the Los Angeles Basin[22] are easily explained by the result presented in this paper.

For urban atmospheres in which pollution is predominantly caused by sulphur dioxide the photo-oxidation rate estimated in this paper indicates a significant conversion of sulphur dioxide to sulphuric acid mist during the day when the atmospheric transmissivity for the region around 300μ is relatively high and the average air path for solar radiation is not too great. The existence of such a process would obviate the necessity of postulating the presence of catalysts[23] to account for the observed fact that sulphur dioxide in such atmospheres can at times be relatively rapidly converted to sulphuric acid. However, extrapolating the rate observed in the reactor to that occurring in sunlight involves possible large errors in estimating the intensity around 300μ within the reactor. For this reason further experimental work is indicated to confirm the estimated rate. It might be pointed out, however, that even in atmospheres polluted predominantly with sulphur dioxide there will be some unsaturated hydrocarbons and nitrogen oxides. The work on 2-methylbutene-2 described above, indicates that low hydrocarbon concentrations can be quite effective in co-photo-oxidizing sulphur dioxide. If this finding holds for typical concentrations in such atmospheres, the question of sulphur dioxide absorption rates and quantum yield for photo-oxidation could become academic.

Reaction Mechanisms in the Photo-oxidation of Sulphur Dioxide

The kinetics and mechanism of this reaction have been investigated by Hall and Blacet.[24] In dry systems and using 3130A radiation, these investigators found sulphur trioxide to be the only product, its rate of production being proportional to the sulphur dioxide pressure. The latter finding was confirmed by Gerhard and Johnstone[25] for parts per million concentrations in wet air, 60–70 per cent R.H., with sulphuric acid being the product. Hall and Blacet also found that, for oxygen pressures greater than 50 mm., the rate of production was independent of oxygen pressures. In the absence of oxygen, the products were sulphur and sulphur trioxide. The mechanism suggested in the absence of oxygen was

$$SO_2 + h\nu \rightarrow SO_2^* \tag{1}$$
$$SO_2^* \rightarrow SO_2 + h\nu \tag{2}$$
$$SO_2^* + M \rightarrow SO_2 + M \tag{3}$$
$$SO_2^* + SO_2 \rightarrow SO + SO_3 \tag{4}$$

and presumably $SO \rightarrow SO_3 + S$ by various steps (5)

In the presence of oxygen the additional steps

$$M + SO_2^* + O_2 \rightarrow SO_4 + M \tag{6}$$

and

$$SO_4 + O_2 \rightarrow SO_3 + O_3 \tag{7}$$

were postulated.[26] Later, (7) was supplemented by (8):[27]

$$SO_4 + SO_2 \rightarrow 2SO_3 \tag{8}$$

The authors prefer to neglect (7) pending proof that ozone can be formed. This mechanism, plus the observed independence of oxygen concentration, requires a quantum yield of 2 in contrast with the fractional yields actually observed. This inconsistency can be avoided by taking advantage of some recent developments in the theory of electronically excited AB_2 molecules.

Molecular orbital calculations by Walsh[28] indicate that the first excited electronic state of sulphur dioxide is a "bent" state, having a different O-S-O bond angle than the ground electronic state. By the Franck-Condon principle, then, the absorption of radiation by sulphur dioxide promotes it into a highly excited vibrational state of the second electronic level, thus complicating somewhat the process represented by (1), (2) and (3). This vibrational ground state can probably be identified with the reactive species of reactions (4) and (6) and we can write:

$$SO_2 + h\nu \rightarrow SO_2^{**} \tag{9}$$
$$SO_2^{**} \rightarrow SO_2 \text{ by various processes} \tag{10}$$
$$SO_2^{**} \rightarrow SO_2^* \text{ by various processes} \tag{11}$$
$$SO_2^* \rightarrow SO_2 \text{ by various processes} \tag{12}$$

The bent state can probably be considered to be a biradical having an unpaired electron in a sulphur sp^3 orbital, thus facilitating reaction (6). The only condition on relative rates imposed by experimental findings is that reaction (6) be much more rapid than the net rate of processes (12) at oxygen pressures greater than about 50 mm. Therefore, the bent ground state is sufficiently stable with regard to collisional deactivation and spontaneous or induced radiation so that it reacts nearly completely with oxygen at these relatively high oxygen partial-pressures and at total pressures ranging from 0·1 to 1 atmosphere. Considerably more work is indicated on the photodismutation and photo-oxidation of sulphur dioxide before the mechanism can be stated in detail with confidence.

The work described in this paper suggests that the reaction

$$SO_4 + NO \rightarrow SO_3 + NO_2 \tag{13}$$

takes place, thus accounting for the possible suppressing effect on the sulphur dioxide photo-oxidation rate by nitric oxide.

In the presence of photolyzing nitrogen dioxide, both reaction (13) and the reaction

$$M + SO_2 + O \rightarrow SO_3 + M \tag{14}$$

must be considered.

Sulphur dioxide at parts per million concentrations cannot compete so successfully with molecular oxygen in air for oxygen atoms as to account for the observed enhancement of dioxide consumption by co-photo-oxidizing olefin-nitric oxide mixtures. Therefore, reaction (14), plus

$$NO_2 + h\nu \rightarrow NO + O \tag{15}$$

and

$$O + O_2 + M \rightarrow O_3 + M \tag{16}$$

plays only a minor role ($R_{14} \simeq 3 \times 10^3$ (SO_2) (O) p.p.m. min^{-1}, $R_{15} = 1{\cdot}2$ (NO_2) p.p.m. min^{-1}*, $R_{16} \simeq 1{\cdot}4 \times 10^6$ (O) p.p.m. min^{-1} with air at atmospheric pressure in the 50-litre reactor). (Nitric oxide is partially converted to nitrogen dioxide during the photo-oxidation.) We must, therefore, look elsewhere for the responsible reactive species. For example, we may write speculatively

$$RO_2 + SO_2 \rightarrow RO + SO_3 \tag{17}$$

but more experimental work is needed before a mechanism can be confidently proposed.

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Table I

Rate of Photo-oxidation of Sulphur Dioxide in 50 per cent R.H. Air

Experiment Number	*Sulphur Dioxide Concentration (p.p.m.)*			*Residence (Min.)*	*Rate of Photo-oxidation* (min^{-1})
	Influent	*Effluent*	*Decrement*		
19 AS	0·61	0·52	0·09	27	0·006
8 AS	0·52	0·47	0·05	17	0·006
11 AS	0·28	0·27	0·01	17	0·002
14 AS	0·22	0·20	0·02	27	0·004

Average $(4{\cdot}5 \pm 1{\cdot}2) \times 10^{-3}\ min^{-1}$ (50 per cent Conf.)

Table II
Light Scattering and Sulphur Dioxide Concentration Data for Photo-oxidation in 50 per cent R.H. Air

Experiment Number	*Residence Time (Min.)*	*Sulphur Dioxide Data (p.p.m.)*					*Light-Scattering Data*	
		Influent		*Effluent*	*Increment*			
		from Tank Data(a)	*Measured(b)*		*Measured(b)*	*Calculated*	*Total referred to Air*	*Count (ml^{-1})*
11 A-1	17	0·11	NI	NI	NI	0·01	0·75	NI
11 A-2	17	0·30	NI	NI	NI	0·02	2·58	32
5 A-2	17	0·47	NI	NI	NI	0·03	< 22	NI
6 A-2	17	0·47	NI	NI	NI	0·03	5·9	174
6 A-4	17	0·47	NI	NI	NI	0·03	9·0	NI
7 A-2	17	0·47	NI	NI	NI	0·03	8·7(*c*)	NI
7 A-4	17	0·47	NI	NI	NI	0·03	0·59(*c*)	NI
7 A-5	17	0·47	NI	NI	NI	0·03	0·19(*c*)	NI
14 AS-1	27	NI	0·22	0·20	0·02	0·02	1·07	NI
17 AS-2	27	0·51	0·63–0·90	0·61	0·02–0·29	0·06	17·9	NI
17 AS-3	27	0·51	0·63–0·90	0·64	< 0·00–0·26	0·06	17·4	1080
17 AS-4	27	0·51	0·63–0·90	0·75	< 0·00–0·15	0·06	15·9	NI
17 AS-6	27	0·51	0·63–0·90	0·71	< 0·00–0·19	0·06	16·9	NI
19 AS	27	NI	0·61	0·52	0·09	0·07	11·3(*c*)	NI
16 AS-5	27	1·02	1·34	1·20	0·14	0·11	24(*c*)	NI
16 AS-6	27	1·02	1·34	0·98	0·36	0·11	17·5	1190
16 AS-2	27	2·27	2·58	2·62	< 0·00	0·25	38·7	1730
16 AS-3	27	2·27	2·58	2·40	0·18	0·25	26·7	NI
15 AS-2	27	4·49	3·48	3·81	< 0	0·49	56	3990
15 AS-3	27	4·49	3·48	4·18	< 0	0 49	55	NI

NI means no information.

(*a*) These concentrations were calculated from the partial pressure of sulphur dioxide in the stainless steel reagent storage tank and flow rates into the mixer.

(*b*) Measurements of sulphur dioxide in the reactor stream were occasionally very inaccurate and indefinite because of wall sorption effects and/or malfunction and slow response of the sulphur dioxide recorder. On those occasions when it was thought that the recorder was at fault, greater reliance was placed on the calculated concentrations.

(*c*) Is used to indicate that the light scattering was varying in a quasi-periodic manner and that the value given is the peak of the variation and that the minimum value is of the same order of magnitude as the peak.

Table IV
Photolysis of Mixtures of 2-Methylbutene-2, Nitric Oxide and Sulphur Dioxide

Experiment Number	*Residence (Min.)*	*Irradiation*	*Influent Concentration (p.p.m.)*			*Effluent Data*		
			SO_2	*HC*	*NO*	*Light Scattering*	*Particle Count (ml^{-1})*	*SO_2 Concentration (p.p.m.)*
3 A-3	17	yes	0·094	2·9	0·96	6·2	242	NI
9 AS-3	17	no	0·11	0·49	0·98	NI	NI	0·11
9 AS-4	17	yes	0·11	0·49	0·98	NI	NI	0·01
9 A-1	17	yes	0·11	0·49	0·98	5·6	NI	NI
10 A-1	17	no	0·11	0·49	0·98	0·00	NI	NI
10 A-2	17	yes	0·11	0·49	0·98	5·2	NI	NI
9 A-2	17	yes	0·11	0·99	0·98	6·4	NI	NI
10 A-3	17	yes	0·11	0·99	0·98	7·3	NI	NI
9 A-3	17	yes	0·11	1·98	0·98	11·1	NI	NI
10 A-4	17	yes	0·11	1·98	0·98	8·4	NI	NI
9 A-4	17	yes	0·11	2·9	0·98	7·4	NI	NI
10 A-5	17	yes	0·11	2·9	0·98	8·7	NI	NI
3 A-4	17	yes	0·19	2·9	0·96	11·8	590	NI
10 A-6	17	yes	0·30	2·9	0·98	14·5	NI	NI
2 A-3	17	yes	0·47	2·9	0·96	6·4	511	NI
3 A-5	17	yes	0·47	2·9	0·96	18·3	896	NI
7 A-7	17	yes	0·47	2·9	0·96	24·2	NI	NI
8 A-1	17	no	0·47	2·9	0·96	0·00	NI	NI
8 A-2(*a*)	17	yes	0·47	2·9	0·96	23·6	1,000 ~	NI
8 A-3(*a*)	17	yes	0·47	2·9	0·96	7·5	358	None
8 AS-3	17	no	0·52	2·9	0·96	NI	NI	0·52
8 AS-4	17	yes	0·52	2·9	0·96	NI	NI	0·40
12 A-1	44	no	0·10	0·50	1·0	0·00	NI	NI
12 A-2	44	yes	0·10	0·50	1·0	9·5	NI	NI
12 A-3	44	yes	0·10	1·0	1·0	8·9	NI	~ ·005
12 A-4	44	yes	0·10	3·0	1·0	9·2	NI	~ ·005
2 A-4	44	yes	0·47	3·0	1·0	22·3	1,028	NI
12 A-5	44	yes	1·0	3·0	1·0	17·8	680	0·4 – 0·5
2 A-5	84	yes	0·47	2·9	0·96	< 26·1	1,200 ~	NI
2 A-6	84	no	0·47	2·9	0·96	→0	NI	NI

NI means no information.

(*a*) Subsequent to experiment 8A-2 the humidifier was bypassed. During experiment 8A-3 the relative humidity was approaching 0·0 per cent.

Table V

Data Showing Increased Rate of Consumption of Sulphur Dioxide due to Photo-oxidation of 2-Methylbutene-2 by Nitric Oxide

Experiment Number	*Residence Time (Min.)*	*Influent Concentration (p.p.m.)*			*SO_2 in Effluent Concentration (p.p.m.)*	*SO_2 Disappearance Rate (p.p.m./Min.)*	*Calculated Photo-oxidation Rate (p.p.m./Min.)*	*Enhancement Ratio*
		HC	*NO*	*SO_2*				
9 AS-4	17	0·49	0·98	0·11	0·01	0·0059	0·00046	13
8 AS-4	17	2·9	0·96	0·52	0·40	0·0070	0·0022	3·2
12 A-3	44	1·0	1·0	0·10	~0·005	0·0022	0·00038	5·8
12 A-4	44	3·0	1·0	0·10	~0·005	0·0022	0·00038	5·8
12 A-5	44	3·0	1·0	1·0	0·45	0·012 ?	0·0038	3·2

Table VI

Light Scattering and Total Particle Count Observed in Photolyzed Mixtures of 3 p.p.m. Hydrocarbon and 1 p.p.m. Nitric Oxide with 50 per cent R.H. Air

Experiment Number	*Hydrocarbon*	*Residence Time (Min.)*	*Light Scattering Referred to Air*	*Particle Count per m.l.*	*Light Scattering at Time of Count*
44 AS	methane	27	0·00	NI	NI
34 AS	n-pentane	27	0·00	NI	NI
32 AS	2-methylbutane	27	0·00	NI	NI
35 AS	2, 2-dimethyl propane	27	0.00	NI	NI
38 AS	cyclopentane	27	0·00	NI	NI
49 AS	ethylene	27	0·00	NI	NI
25 AS	1-pentene	27	0·04	NI	NI
23 AS	2-methyl 1-propene	27	0·00	NI	NI
1 A-1	*trans* 2-butene	21	0·00	NI	NI
18 AS	*trans* 2-butene	27	0·00	NI	NI
21 AS	*trans* 2-butene	27	0·00	NI	NI
2 A-2	2-methylbutene-2	17	< 0·22	< 14	~0·22
3 A-2	2-methylbutene-2	17	0·60	NI	NI
29 AS	2, 3-dimethylbutene-2	27	0·19	NI	NI
30 AS	2, 3-dimethylbutene-2	27	0·30	NI	NI
27 A	cyclohexene	27	0·26(ss)	179	7·6 (transient peak)
28 AS	cyclohexene	27	< 11·1	290	11·1 (peak of light scattering)
31 AS	cyclohexene	27	10·8	NI	NI
41 AS	cyclohexene	27	8·2–14·2	NI	NI
22 AS	1, 3-butadiene	27	0·38	NI	NI
47 AS	1-butyne	27	0·00	NI	NI
42 AS	benzene	27	0·00	NI	NI
50 AS	toluene	27	0·00	NI	NI
48 AS	ethyl benzene	27	0·00	NI	NI
40 AS	p-xylene	27	0·00	NI	NI

NI means no information.

Table VII

Light Scattering and Total Particle Count Observed in Photolyzed Mixtures of 3 p.p.m. Hydrocarbon, 1 p.p.m. Nitric Oxide, and Sulphur Dioxide with 50 per cent R.H. Air

Experiment Number	*Hydrocarbon*	*Residence Time (Min.)*	*Sulphur Dioxide Concentration (p.p.m.)*		*Enhancement Ratio(a)*	*Light Scattering Referred to Air*	*Particle Count*	
			Influent	*Effluent(a)*			*cm⁻³*	*Light Scattering*
44 AS	methane	27	0·03–0·10	0·00	<8·9	0·00	NI	NI
44 AS	methane	27	0·14	0·14	0·0	1·80	NI	NI
34 AS	n-pentane	27	0·03–0·10	0·00	<8·9	0·00	NI	NI
34 AS	n-pentane	27	0·14	0·15	0·0	0·00	NI	NI
32 AS	2-methylbutane	27	0·03–0·10	0·01	<8·0	0·00	NI	NI
33 AS	2-methylbutane	27	0·03–0·10	0·01	<8·0	0·00	NI	NI
35 AS	2, 2-dimethyl propane	27	0·03–0·10	0·00	<8 9	0·00	NI	NI
35 AS	2, 2-dimethyl propane	27	0·14	0·01	<8·3	0·22	NI	NI
38 AS	cyclopentane	27	0·03–0·10	0·00	<8·9	0·00	NI	NI
38 AS	cyclopentane	27	0·14	<0·08	<3·8	0·00	NI	NI
49 AS	ethylene (6 p.p.m.)	27	0·03–0·10	0·00	<8·9	0·06	NI	NI
49 AS	ethylene (6 p.p.m.)	27	0·14	0·16	0·0	2·70	NI	NI
25 AS	1-pentane	27	0·27	0·14	4·3	7·7–13·6	172	7·8
23 AS	2-methyl 1-propane	27	0·27	0·19	2·6	2·0–6·9	17	1·6
1 A-2	*trans* 2-butene	21	0·47	NI	NI	16	248	~16
18 AS	*trans* 2-butene	27	0·61	0·36	3·6	16·1	NI	NI
21 AS	*trans* 2-butene	27	0·27	0·00	8·9	<10·5	NI	NI
21 AS	*trans* 2-butene	27	0·39	0·29	2·3	16·1	710	16·1
2 A-3	2-methylbutene-2	17	0·47	NI	NI	6·4	511	6·4
3 A-3	2-methylbutene-2	17	0·09	NI	NI	6·2	240	6·2
3 A-4	2-methylbutene-2	17	0·19	NI	NI	11·8	590	11·8
3 A-5	2-methylbutene-2	17	0·47	NI	NI	18·3	900	18·3
29 AS	2, 3-dimethylbutene-2	27	0·27	0·00–0·11	<5·3	2·0–6·3	22	2·0
30 AS	2, 3-dimethylbutene-2	27	0·09	0·00	8·9	17·9	NI	NI
28 AS	cyclohexene	27	0·27	<0·06	<6·9	3·8–23·4	129	6·4
31 AS	cyclohexene	27	0·03–0·10	0·00	8·9	6·4–13·1	NI	NI
22 AS	1, 3-butadiene	27	0·27	0·15	6·9	16·7	509	13·8
47 AS	1-butyne	27	0·03–0·10	0·00	8·9	0·00	NI	NI
47 AS	1-butyne	27	0·14	0·14	0·0	0·11	NI	NI
42 AS	benzene	27	0·03–0·10	0·00	8·9	0·06	NI	NI
42 AS	benzene	27	0·14	<0·13	0·0	0·98	NI	NI
50 AS	toluene	27	0·03–0·10	0·00	8·9	0·00	NI	NI
50 AS	toluene	27	0·14	0·05–0·35	?	2·00	NI	NI
48 AS	ethyl benzene	27	0·03–0·10	0·00	8·9	0·00	NI	NI
48 AS	ethyl benzene	27	0·14	0·16	0·0	2·70	NI	NI
40 AS	p-xylene	27	0·03–0·10	0·00	8·9	0·00	NI	NI
40 AS	p-xylene	27	0·14	0·08	3·8	0·00	NI	NI

NI means no information.

(*a*) Measurements of effluent sulphur dioxide concentration and values of the enhancement ratio calculated from these measurements are in considerable doubt, particularly at the lower influent sulphur dioxide concentrations because of difficulties in establishing and measuring low concentrations in the apparatus. The enhancement ratio is the ratio of rate of disappearance of sulphur dioxide to that expected from sulphur dioxide photo-oxidation alone and can be no greater than 8·9 at a residence time of 27 minutes if the photo-oxidation rate is 0·0046 min^{-1}.

(*b*) This column gives light scattering at the time the count was made.

THE PHOTOGRAPHY OF AIR POLLUTION

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SUMMARY: The author discusses the uses of photography in air pollution observations and investigations and with the aid of examples illustrates the values, limitations and possibilities of error associated with such work.

Solid objects with sharp edges are rather easy to photograph in comparison with clouds and air pollution. There are certain standard techniques, such as the use of polarizers and orange filters, for making clouds stand out when the sky surrounding them is blue, but they fail when the sky is hazy and orange, grey and overcast, or when the visibility is poor. They also fail with grey or white smoke and it is therefore often necessary to choose carefully the point of observation.

The grey smoke from the steam locomotive in Plate I is darker than the sky but lighter than the buildings. It has been made visible by taking it from a point higher than the source in a direction directly downwind, thereby increasing its opacity. The smoke from tall chimneys can sometimes be seen more clearly by viewing it from directly downwind, especially when it is descending and obscuring the chimney top: when viewing it from any other angle one cannot usually tell whether or not it is descending because of the effects of perspective. The white plume from the cement works in Plate II is made visible by showing it against a hillside.

Of course we cannot always get to an ideal viewpoint, and our subjects do not normally pose for us. On the other hand, many of us do get into all sorts of unexpected places and the only answer is to carry our cameras everywhere in the hope that scenes of the kind we wish to record will occur. Plate I was taken while examining a new design of roof.

One must be ready to recognize interesting but unexpected things. For example, the standard technique for illustrating dirty buildings is to show pictures of them before and after cleaning. This can be faked in the dark-room quite easily, but the comparison is too obvious to be of any scientific value anyway. More interesting are the buildings which are dirty only in parts. Why, for example, do the shadows on the flying buttress on Lincoln Chapter House (Plate III) show when the sun is not shining? Clearly it is not a question of washing by rain but simply that the black stuff, whatever it is, doesn't grow so well in sunshine. This particular stonework only gets sunshine from within 30° of S.E. for most of the year.

Photographs of smoky cities do not look impressive unless there is a basis of comparison. One trick is to show " Sunday " and " Monday " pictures of some industrial town, side by side. They prove nothing because the weather has a much greater effect than the day of the week and it is too easy to cheat anyway. Thus Plates IV (a) and (b) are views of Liverpool " demonstrating the advantages of smokeless fuel ". They were taken about three minutes apart, one by infra red light, on a muggy but not particular y smoky day.

By careful selection of the place and moment one can " demonstrate " fallacies. For example Plate V is quite natural (but was taken at the top of a cliff).

Plate VI is not an attempt to prove that the colliery in question was making dark smoke, but this temporary dark emission happens to provide a good illustration of atmospheric eddies which are significantly different in structure from those of Plate II. Dark smoke cannot be *proved* by photography because it can so easily be faked. Plate VII (a), (b) are actually the same photograph of a steelworks smoke plume. VII (a) shows it by red light and VII (b) by blue light, and they are both copied from the same colour picture. The plume itself was bright orange red.

Plate VII illustrates the principle that it is better to take the picture in colour first and try out filters later. Generally much more contrast can be obtained in this way than by using black and white film and hurriedly selecting filters at the time.

The easiest kind of smoke to photograph is that which comes from tall chimneys when it is dense or coloured. It shows up well in bright sunshine on a clear day and it is under such conditions that a professional photographer will take pictures of it if commissioned to do so. But what if he is asked to record the cause of widespread visibility?

Plate VIII shows a district known as West Wimbledon, where there are only two significant kinds of smoke source—bonfires and domestic fires. On this sunny day (Oct. 28, 1958, 16 h. G.M.T.) there was an inversion at about 300 ft and this suburb was literally stewing in its own juice. Such is the habit of our cities and suburbs on many winter nights every year, but I know of no method of demonstrating to the incredulous that this really does happen after dark except by showing that it can happen under meteorological conditions which often occur at night.

On one occasion a few years ago when I was riding this particular hobby horse I was accused of selecting the pictures to prove my points. Actually I showed all the pictures I possessed at the time—no selection was made. But nothing is proved by the pictures anyway. What they do is to draw attention to conditions of the atmosphere (or buildings) which were passing unnoticed: they help people to be observant and make it easier for them to believe that what our knowledge of the behaviour of the atmosphere tells us must be happening, really is happening.

That, of course, is a personal viewpoint, but there are much more important corollaries. The camera must be carried everywhere, like a sketchpad or notebook, so that it is ready for any eventuality. One must be psychologically prepared for the unexpected or the unexpected will not be noticed. If no photographs were ever used for the persuasion of others, the search for subjects and the taking of them would be entirely justified by what the photographer himself discovers. He sees illustrations of his critic's points; he becomes aware of new processes of smoke accumulation and dispersion. The discipline of recording an event by photograph and making notes of the occasion is an aspect of the experimental and observational scientist's technique which is well-known for the valuable mental stimulus it can provide. But the stimulus comes not from seeing again what one believes in. Illustrations of what one " knows " to be true can be dangerously sedative. Rather one should seek to disprove every cherished theory: one soon discovers how naive they are. Knowledge consists in having grounds for abandoning theories.

Plate I. Railway smoke at Brayford, Lincoln.

Plate II. Cement works, Bradwell, Derbyshire.

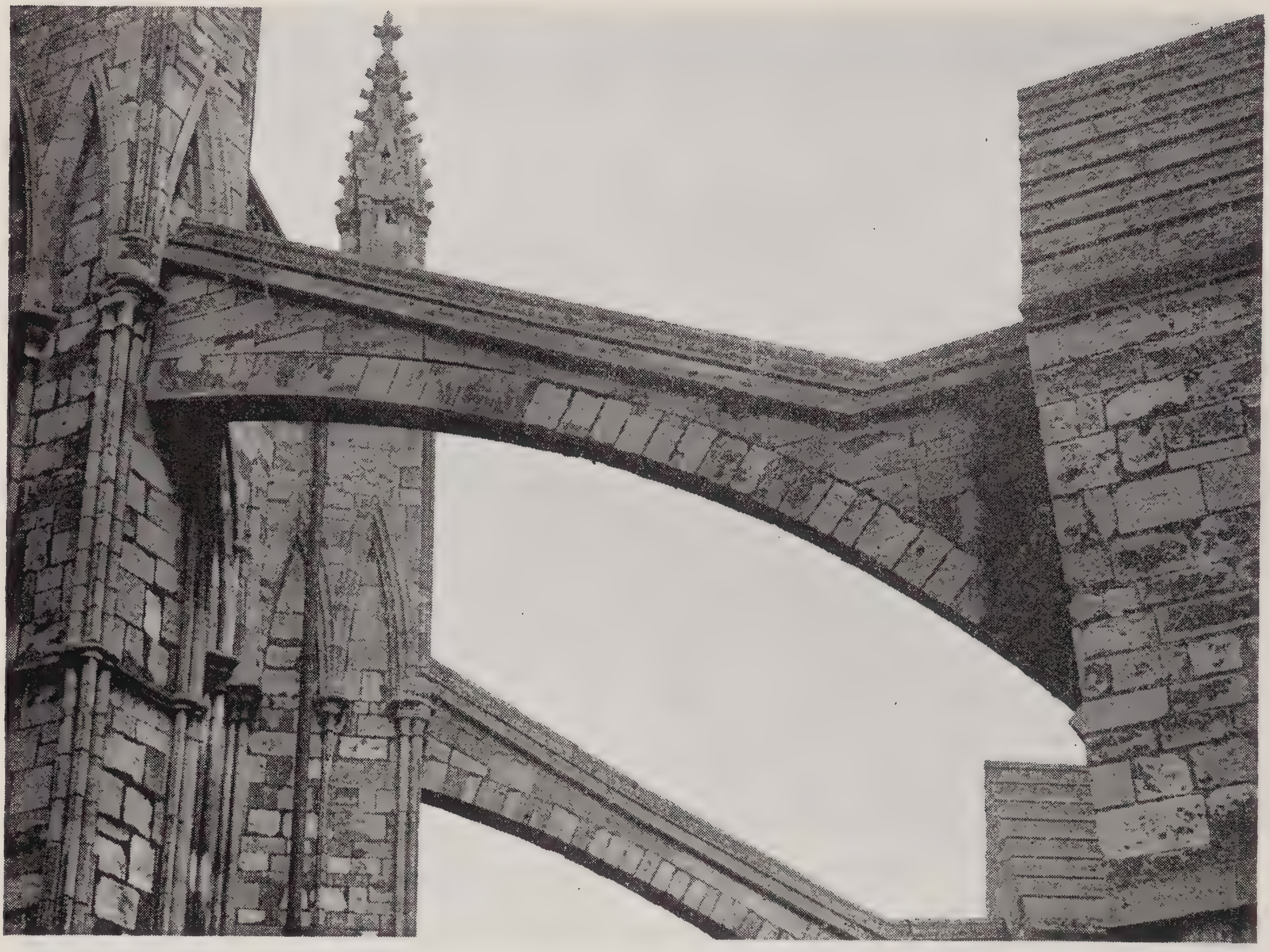


Plate III. Blackening on Lincoln Cathedral Chapter House.

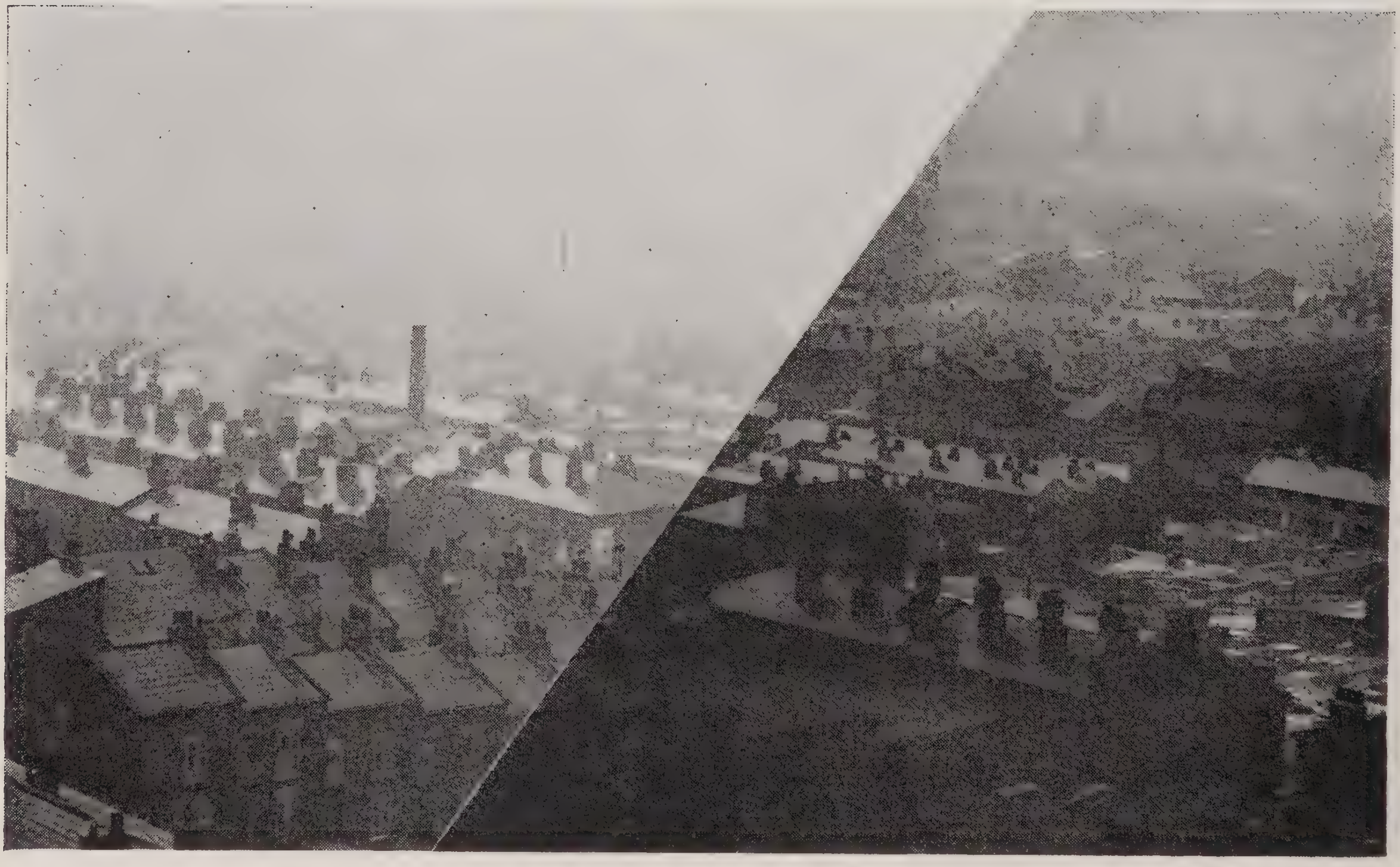


Plate IV. Liverpool seen from a new block of flats. (a) and (b).

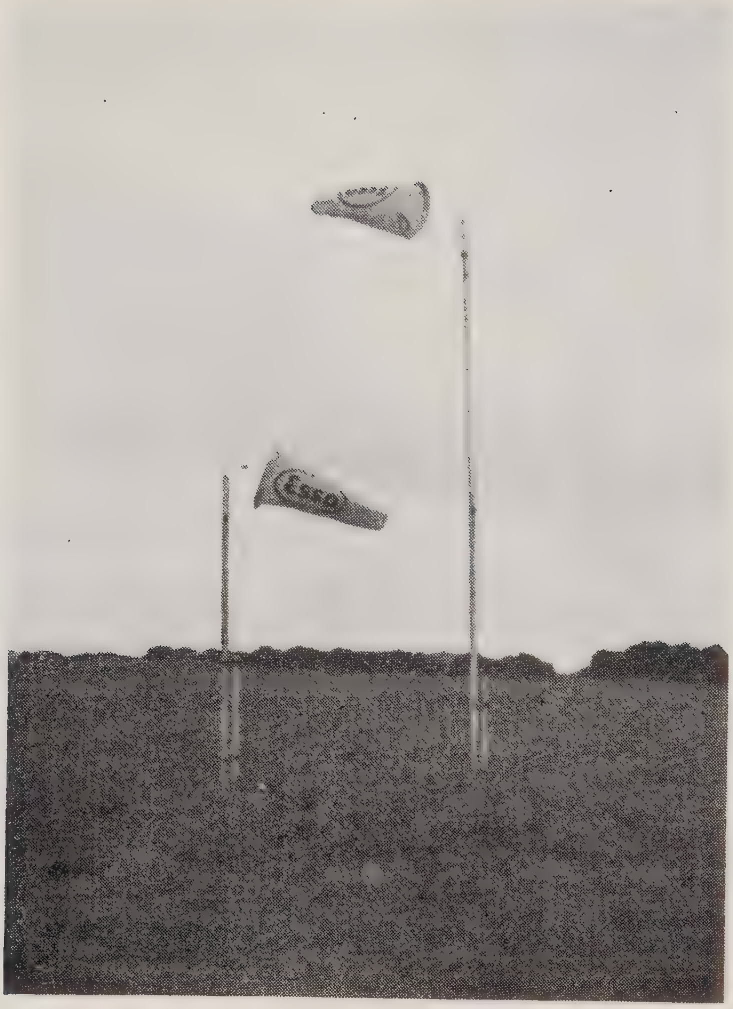


Plate V. How to illustrate queer behaviour of the wind.

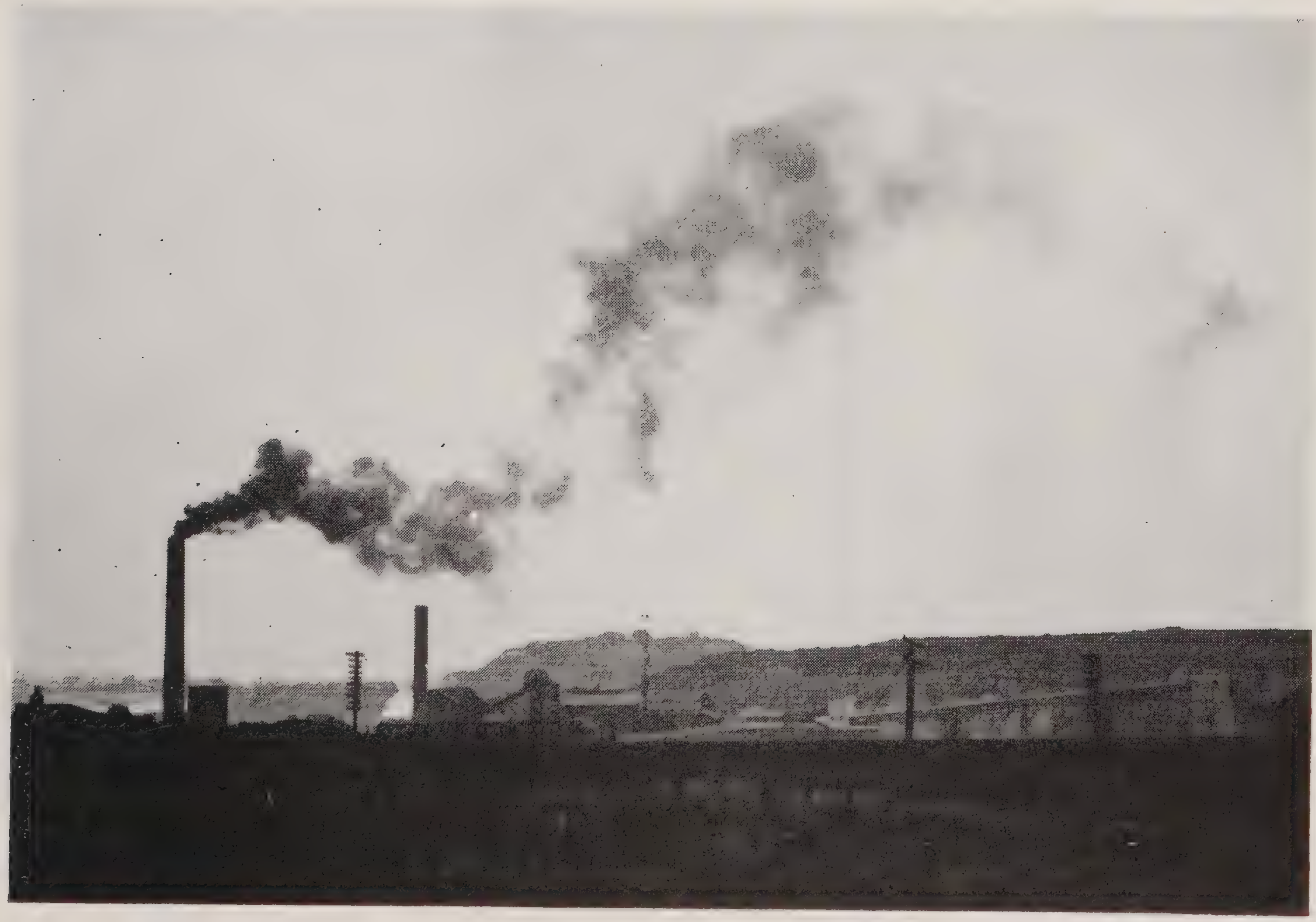
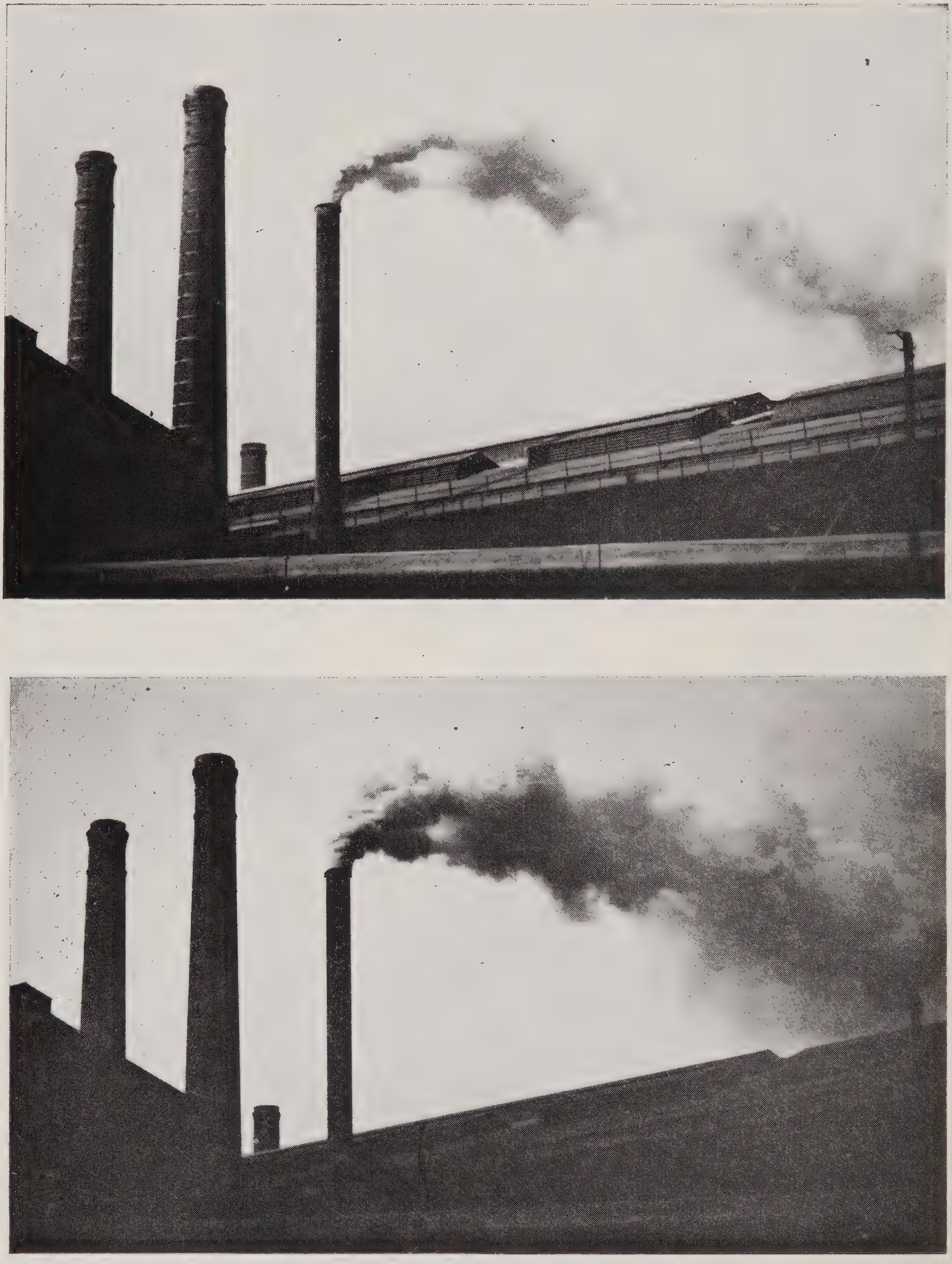


Plate VI. Black smoke from a colliery near Chesterfield showing the atmospheric eddies



Plates VII. (a) and (b). Red dust plume at Scunthorpe seen through red and blue filters.

Plate VIII. West Wimbledon obliterated by a shallow layer of domestic smoke.

V. 76

THE PENETRATION OF INVERSIONS BY HOT PLUMES

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SUMMARY: It is possible to calculate the heat rate required in a chimney to ensure penetration of an inversion of known height and intensity. High chimneys are essential. Chimneys serving 100 MW of plant or more will penetrate the worst inversions. There is need for more information on inversions.

Introduction

On rare occasions large cities are enveloped by persistent fog which quickly becomes contaminated by atmospheric pollution. The temperature inversion which gives rise to the fog also effectively traps the effluent emitted from domestic and industrial chimneys. London experienced such a fog in December 1952, and Manchester in November 1955. In the London area 4,000 deaths have been attributed to the high pollution and the fog[1] and in Manchester much the same concentrations of sulphur dioxide were measured.

It has been shown[2] that domestic fires are responsible for a good deal of pollution in cities and since domestic chimneys emit smoke at a low level and at low temperatures there is no doubt that pollution from these sources cannot escape from the fog layer. On the other hand, power stations produce a large amount of sulphur dioxide and it is of importance to know whether or not hot plumes emitted from high chimneys succeed in penetrating the fog layer.

By using formulae derived by Priestley[3] and Sutton[4] it is possible to estimate the amount of heat required to carry a plume through an inversion of known height and intensity.

Method of Investigation and Results

Theories are of limited use unless numerical values can be applied to the formulae emerging from the theories. It was decided to examine the two specific instances of fog already mentioned and to find by calculation how hot a plume would have to be to penetrate these known inversions, before drawing any general conclusions about the penetrating power of hot plumes.

Basically, air is entrained continuously into a hot plume during its ascent and as the mixture of air and gas rises it cools adiabatically. To penetrate an inversion, the final temperature of the plume must be greater than the environment temperature at the top of the inversion.

The application of Sutton's equation to the problem involved a good deal of computation in the form of integration by addition and for a more detailed appraisal reference should be made to the original paper.[5] Priestley's formula proved to be more amenable in that the ceiling height of a plume can be calculated directly from the known basic quantities. It is sufficient to say that the application of the formulae by Sutton and Priestley produced substantially the same result.

Priestley's ceiling height given by

$$Z_c = 4{\cdot}9 \left(\frac{g}{T} \cdot \frac{d\theta}{dz}\right)^{-\frac{3}{8}} \left(\frac{g}{T} \cdot \frac{Q}{\pi p \cdot c_p}\right)^{\frac{1}{4}} \text{ cms}$$

where T = air temperature (°A)

$\frac{d\theta}{dz}$ = potential temperature gradient (°C/cm)

Q = heat content of plume (cals/sec).

To apply the formulae it was assumed that the stack height was 300 ft and the diameter of the mouth 20 ft. From such a stack the heat content of plumes required to penetrate the London and Manchester fogs are shown in the Table.

More generally, if h_c is the height of the top of the inversion, h is the height of the stack, and r_0 the radius of the stack, a hot plume will clear the inversion if

$$Z_c + h - 10r_o > h_c$$

Thus, for any occasion, if the height of the top of the inversion is known as well as the potential temperature gradient of the fog layer, a value of the heat content of the plume can be found which will ensure that the plume will penetrate the inversion.

Discussion

The investigation has emphasized a number of points.

1. It is of great importance that the stacks should be as high as possible. In the London case, hot gases were released only 200 ft from the top of the fog and as a result the heat required was only one-hundredth of that required in the Manchester case.
2. There is a need for information on the frequency of inversions of different depths, as well as on the temperature profile within the inversions. Detailed information of temperature within the lowest 1,000 ft of the atmosphere is very sparse. Records from Cardington show that the majority of inversions extend from the surface to between 750 and 1,000 ft. It appears likely that a deep inversion as experienced at Manchester will only occur once or possibly twice in four years.
3. The amount of plant attached to one chimney varies considerably among existing power stations. 60 MW per chimney is probably representative of stations about 15 years old. More modern stations have 100 MW or more per stack. Hence it is likely that plumes from modern stations will penetrate the worst possible atmospheric inversion associated with fog; with many existing stations the penetration will depend on the severity of the inversion.

Fog	*Stack Height*	*Stock Diameter*	*Air Temp.*	*Height of Inversion*	*Pot. Temp. Gradient*	*Heat Content Required*
London, 1952 ...	300 ft	20 ft	273°A	500 ft	$2{\cdot}5 \times 10^{-4}$ °C/cm	$0{\cdot}1 \times 10^6$ cals/sec
Manchester ...	300 ft	20 ft	273°A	1,500 ft	$2{\cdot}0 \times 10^{-4}$ °C/cm	$11{\cdot}5 \times 10^6$ cals/sec

Experimental Evidence

Aircraft flights have been made over fog in the London basin and a series of photographs were taken which show conclusively that hot plumes penetrate the fog layer and stream away from their point of emergence in the moving air above.

Conclusions

It is possible to calculate the heat rate required in a plume to ensure that it penetrates any inversion of known height and intensity. With calm or very light winds a power station plume from a chimney serving 100 MW of plant or more will penetrate the worst inversion on record. Knowledge of the frequency of inversion is inadequate and arrangements are being made to use the B.B.C. Television Mast at Crystal Palace to record continuously the temperature profile of the lowest 1,000 ft of the atmosphere.

Acknowledgement

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AIR POLLUTION IN THE CITY OF LONDON

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SUMMARY: Since 1954 measurements of air pollution have been taken at St. Bartholomew's Hospital in the City of London smokeless zone. During " smog " incidents the sulphur dioxide level is found to be higher than the smoke level when the air is still, or when there is some wind from the West (from the commercial areas). When the wind is from other directions smoke predominates, presumably carried from domestic fires. There was also a complete absence of very high levels of smoke during the winter 1958/1959.

Since October 1955 the emission of smoke has been prohibited in the one square mile of the City of London and even before then it was low in comparison with some residential boroughs. In the remaining 721 square miles of Greater London there is still substantial smoke emission and winds from any direction bring some of it into the City. The greatest contrasts between the City and adjoining boroughs occur during periods of low temperature inversion in the winter. Then pollution cannot disperse upwards into the atmosphere and if there is no wind it accumulates where emitted. In December 1952 these conditions persisted for five days and the wind was reported as nil for much of the time. Daily measurements of smoke and sulphur dioxide were being made in the City and elsewhere in London but there was so much smoke that it blocked the filters and this made accurate measurement difficult. It seems likely that the concentration of smoke was higher than any recorded since, and although conditions were very stable there may have been a certain amount of air movement bringing smoke from other areas into the City from time to time.

Additional measurements of atmospheric pollution have been made at St. Bartholomew's Hospital since 1954 and during periods of temperature inversion the concentrations of smoke and sulphur dioxide have been measured hourly. There have been six episodes of sufficient duration or intensity to warrant special mention, but none of them has lasted as long as the one in December 1952. In each there has been just enough wind to bring in pollution from other boroughs and there have been marked variations in the relative amounts of smoke and sulphur dioxide recorded.

During the first of these episodes in January 1955, pollution was intense but did not persist for long. A thick pall of smoke moved in from the south and the concentration reached over 6 mg/m^3 (Fig. 1) The concentration of sulphur dioxide rose at the same time to a maximum of 1 p.p.m. On the next occasion, in January 1956, the pollution drifted in from the north-west and at one time a "wall" of smoke could be seen on the northern boundary of the City. The area around the Hospital remained quite clear for several hours after, but when this polluted air did drift across, the concentration of smoke reached 10 mg/m^3 (Fig. 2). Sulphur dioxide reached 0·7 p.p.m. at that time, but during the second day of the episode, when there was a very light easterly wind, it reached 1 p.p.m. with less smoke than before.

There were no periods of prolonged high pollution during the winter of 1956/57 and the next was in December 1957. There was a light easterly breeze for the first 48 hours and the concentration of both smoke and SO_2 was very high (Fig. 3). Later the wind became westerly bringing high concentrations of SO_2 with much less smoke than before. This pattern of only moderate concentrations of smoke with high levels of SO_2 was repeated in another episode in January 1958 (Fig. 4). In this episode there was a light westerly breeze at first, which later became easterly.

Stable air conditions occurred quite frequently during last winter, 1958/59, and on two occasions pollution persisted at a high level for several days. In the January incident (28th–30th) there was a little wind at the beginning and end, mainly from the east, and at times the concentrations of smoke and sulphur dioxide were both high (Fig. 5). The air was exceptionally calm throughout the second day (29th January) and although the concentration of smoke remained about the same, that of sulphur dioxide increased still further. A few weeks later there was another episode (17th–19th February) in which very calm conditions persisted for nearly three days. A very light variable wind brought pollution from several directions into the City from time to time, giving a high concentration of smoke with very high concentrations of sulphur dioxide (Fig. 6).

The graphs presented here have all been drawn to the same scale so that comparisons can be made between the amounts of smoke and sulphur dioxide observed on each occasion. There are marked differences in the ratio of smoke to SO_2 between episodes and sometimes between successive days during the same episode. They are related to the wind direction at the time, and it seems likely that the several directions bring different types of pollution into the City. Although no smoke is emitted in the City itself, the emission of sulphur dioxide is similar to that elsewhere, for coal, coke and fuel oil all contain sulphur. When conditions are very calm the pollution recorded at St. Bartholomew's Hospital is mainly of local origin and contains a very low ratio of smoke to sulphur dioxide. A light west wind also brings in similar pollution, for the emission of smoke is low from the area of mainly commercial premises which extends for four miles west of the Hospital. A light east wind brings a higher proportion of smoke, for the smokier domestic emission begins about one mile from the Hospital in that direction. Similarly, this type of emission begins about three-quarters of a mile to the south and about half a mile to the north of the Hospital, and light winds from these directions bring in still higher proportions of smoke.

Because of these variations with wind direction, it is difficult to establish any definite trend over the years, but the complete absence of very high levels of smoke last winter is interesting. It may have been that the wind failed to bring the maximum levels of smoke into the City at any time, but it remains possible that the emission of smoke has begun to fall off in several directions around the City. It is already clear that the West End is almost as smoke-free as the City and the gradual replacement of large areas of houses by modern blocks of flats in other adjoining boroughs might also be having some effect. The concentrations of SO_2 recorded during the two episodes last winter were higher than in the four previous ones, but it is too early to say whether this suggests any tendency towards increased emission in and around the City. The yearly averages have in fact remained fairly steady over the past few years and the high values might well be attributable to the very stable atmospheric conditions during these two episodes. In February the weather was very similar to that which produced the great "smog" of 1952 and the fact that smoke failed to reach anything like the same levels is a tribute to all that has been done in the last seven years.

The observations reported here form part of a detailed study of the effects of atmospheric pollution on health and we would like to record our appreciation of the assistance given by Dr. P. J. Lawther, the Director of this Group.

Figs. 1–6

Concentration of smoke and sulphur dioxide in the City of London during periods of high pollution, 1955-59.

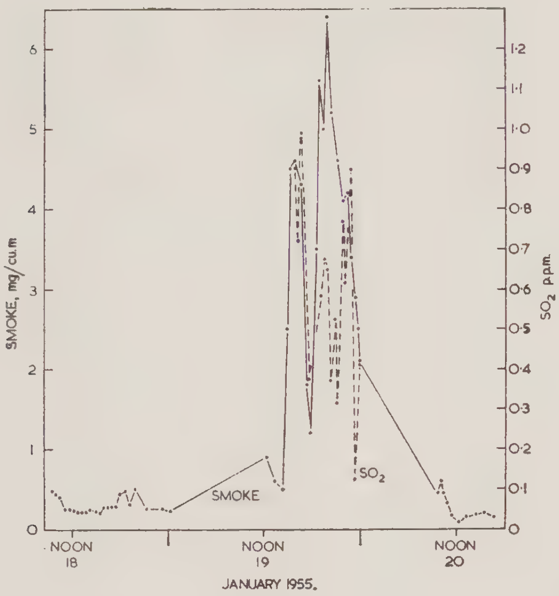

Fig. 1

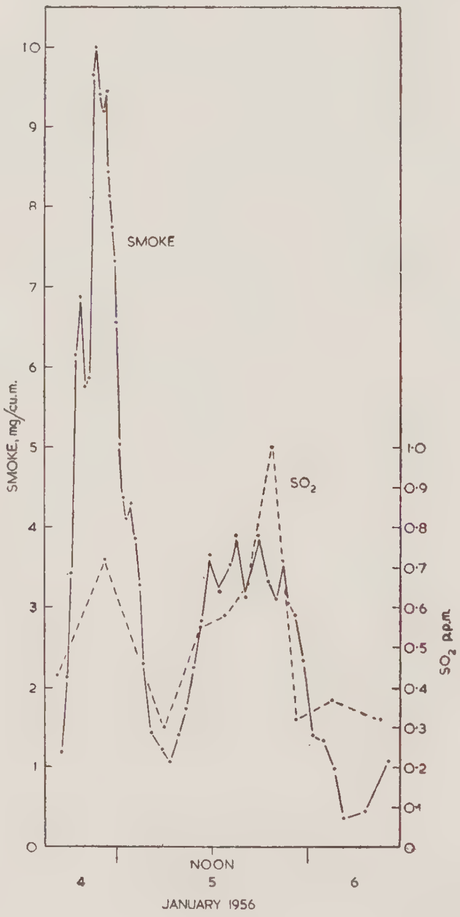

Fig. 2

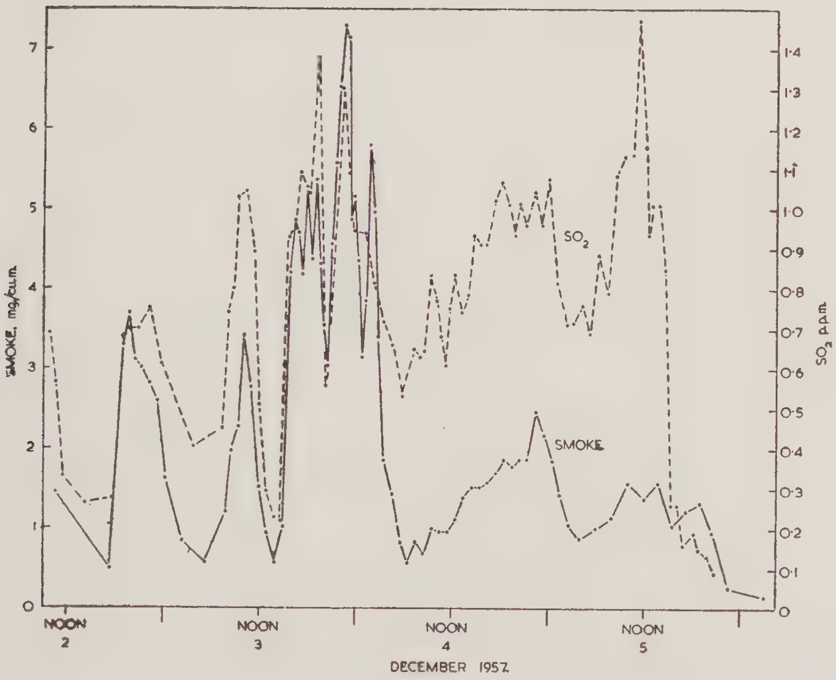

Fig. 3

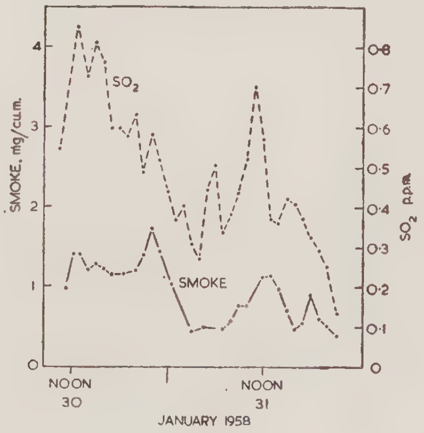

Fig. 4

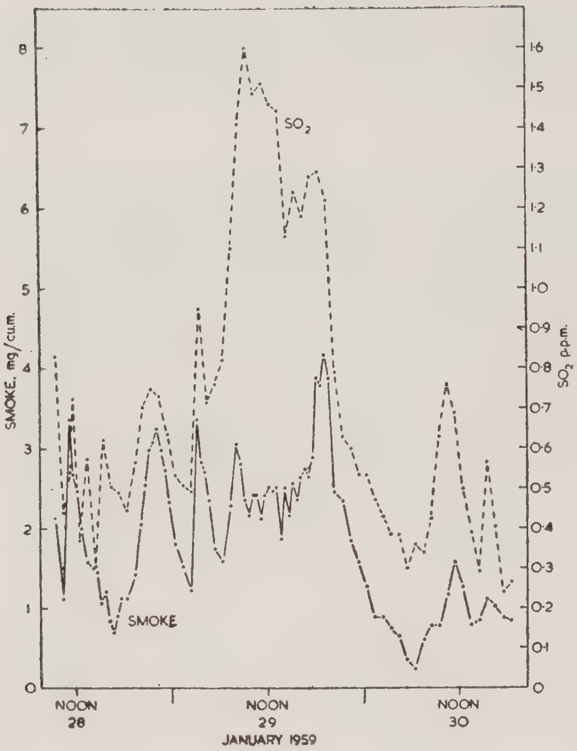
SMOKE, mg/cu.m.
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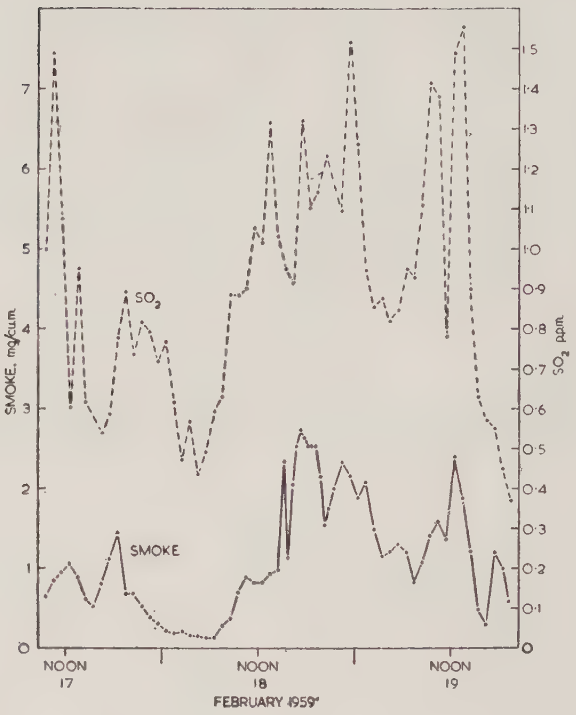
Fig. 5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FEBRUARY 1959

Fig. 6

V. 78

THE USE OF TRANSPARENT SCALE MODELS IN THE DESIGN OF DUST COLLECTOR AND GAS DUCT SYSTEMS FOR COAL-BURNING ELECTRIC GENERATING STATIONS

E. F. WOLF, H. L. VON HOHENLEITEN, M. B. GORDON, Baltimore Gas and Electric Company, U.S.A.

SUMMARY: Dust collecting equipment now forms a large part of the investment in new generating stations, but the efficiency may still be low if the flue gas ducts are ill-designed. At the same time, it must be fitted into the space available. The use of transparent scale models greatly assists the design of the ducts. A specific example is given with illustrations.

In the design of modern electric generating stations in the United States, the avoidance of atmospheric pollution has become a highly important matter in recent years. In the Electric Utility Industry, our neighbours are our customers, and these neighbours insist on clean air. The fly ash collector, therefore, is a very essential, but rather costly, part of a coal-burning power plant. It has gained in importance constantly since World War II because of growing population density and increased generation of electric power. Generating stations must be constructed near population centres, but suitable locations for new stations have become scarce in most sections of this country. With the increased demand for electric power, coal consumption for this purpose has doubled in the past 12 years, and reached 155 million tons in 1958. A large part of this coal is burned in pulverized form; therefore, it is necessary to collect millions of tons per year of finely divided ash from flue gases. These few facts give some idea of the practical importance of the dust collectors in generating stations and of the necessity for their proper performance.

The cost of dust collectors commonly used in American power plants, with the associated fly ash handling equipment and the supporting structures, is about 3–5 per cent of the cost of the entire generating station. Even with such a large investment, the collection efficiency may be low if the flue gas ducts leading to and from the dust collectors are not designed to produce good gas distribution. In spite of its importance, the dust collector system contributes nothing towards improved plant efficiency, and, therefore, its design must be subordinate to the design of the major components of the plant. It must be fitted into the space available. Therein lies the crux of the problem. In this paper we will discuss scale model techniques which have been found to be very useful aids in the design of economical and effective gas duct systems and in their co-ordination with the dust collector.

The equipment used for removal of fly ash from power plant flue gases may be either an electrostatic precipitator, a mechanical collector, or a combination of these two in series. The ash from different coals and different furnaces may differ widely in fineness, unburned carbon content, specific gravity, electric conductivity, and other physical and chemical properties. These properties affect the relative ease of collection by different devices and hence influence the selection of collecting equipment for a given plant.

It has been recognized for many years that the performance of a dust collector is affected by the properties of the ash. It is only in more recent years that the influence of the inlet and exit duct design on the operation of a collector has been fully recognized. Good gas distribution in the whole gas duct system and especially in the approach ducts is necessary for the best utilization of the costly fly ash collecting equipment.

In the design of a duct system, certain factors must be considered and certain requirements must be met. The principal items are enumerated below:

1. The collector and duct systems must be fitted within the space limitations dictated by the overall layout of the major plant components. Space is costly, and the transition in duct cross-section from the relatively small air preheater outlet to the relatively large collector inlet must be made within a distance which is usually too short for good gas flow without the aid of guide vanes or other contrivances.
2. The duct system must be fitted within limitations imposed by the structural supporting members.
3. The duct system must be designed so that it can be constructed at a reasonable cost.
4. The gas must be delivered into the entrance of the collector with sufficient uniformity to permit proper functioning of the collector. Poor gas distribution interferes with good performance of both mechanical and electrostatic types of collectors. Good gas distribution is particularly important with electrostatic precipitators because their efficiency varies appreciably with gas velocity.
5. The dust loading of the gas at the entrance to the collector should be reasonably uniform. However, the means of controlling the dust distribution are limited. The dust loading may not be uniform at the point of exit from the boiler and low velocity duct sections act as settling chambers.
6. The duct system should be designed for minimum practical pressure drop for economy of operation. The gas velocity distribution at the entrance of the collector should be sufficiently uniform that high-loss perforated distributing plates are not necessary.
7. If the system contains induced draft fans, the gas must be delivered to them in sufficient uniformity of flow to prevent pulsation between parallel fans to insure good fan life.
8. The system must be designed to prevent excessive settlement and build-up of fly ash in the ducts.
9. The gas flow pattern must be such that the ash collected in the precipitator hoppers is not picked up by gas swirls and re-entrained.
10. The physical layout of the duct and guide vanes must permit entrance for inspection, cleaning, and maintenance.
11. The gas flow system must give optimum performance at full load and yet satisfactory performance at reduced load, particularly with respect to settlement of fly ash, moisture condensation, corrosion, or clogging of mechanical collector tubes.

12. Gas sampling sections should be provided in the structure for measurement of collection efficiency.

Means of Obtaining Desired Gas Flow Pattern

Six principal means of obtaining good gas distribution are used. They are:

1. Basically good structural shapes for the duct sections.
2. Optimum angular changes of direction of duct systems within the limitations imposed by plant layout.
3. Contouring of the duct to conform as near as practical to natural gas flow.
4. Guide vanes.
5. Sub-division of ducts into continuous gas lanes from high velocity sections to low velocity sections.
6. Resistance screens.

The requirements for dust collectors, the basic principles of application, and means available to achieve good gas flow, which have just been mentioned, are familiar to engineers who design dust collectors and gas duct systems. However, the proper application of this knowledge is not easy to achieve.

Use of Scale Model Approach

About 12 years ago, the engineers of the Baltimore Gas and Electric Company were faced with the necessity of fitting a large electrostatic precipitator and gas duct system into a relatively small space between the air preheater and the stack in an extension to an existing plant. A system was tentatively designed to meet the space requirements. The layout looked reasonably good on the drawing board; however, the angular changes were fairly sharp in both the horizontal and vertical directions. Some further investigation of the expected gas flow pattern was deemed advisable. This company has had very good experience in the use of scale models as an aid in the solution of a fairly wide range of design problems, such as the design of stack structures for good gas dissipation, coal chutes and bunkers to prevent clogging, the approach channels for condenser circulator pumps, and erosion studies in discharge canals. It was decided, therefore, to apply the scale model technique to the study of gas flow in the duct system and precipitators for the generating station extension.

In the model, which was constructed according to the original design, about 65 per cent of the gas passed through one-fourth of the cross-section of the precipitator, and reverse currents of gas circulated through the lower half. The need for change was apparent, but the location of major structural steel members placed serious restrictions on what could be done. However, by improvements in the shape of the approach duct sections and by liberal use of horizontal and vertical guide vanes, the gas distribution was improved by successive steps until very close to one-fourth of the gas passed through each quarter of the precipitator model. The duct system was constructed to agree with the model developments, and a similar degree of uniformity of flow was obtained in actual service.

Since this first model study, four additional new plant installations of different types and configurations have been designed with the aid of scale models. With the experience gained in each successive unit, it has been possible to make better layouts in the drafting board stage. Fewer changes in duct designs and lesser use of vanes have been required in the model stage, to attain satisfactory gas distribution and to avoid accumulation of fly ash in ducts.

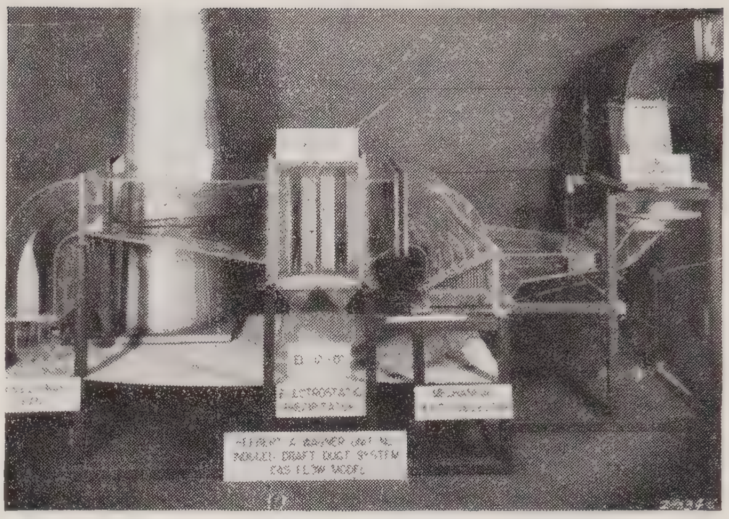
ELECTROSTATIC PRECIPITATOR
HERBERT A. WAGNER UNIT NO.
INDUCED DRAFT DUCT SYSTEM
GAS FLOW MODEL

Fig. 1

Specific Example of a Model Study

As a specific example, the model study of the flue gas duct for the first unit of the Herbert A. Wagner generating station will be discussed in some detail. In this installation, a Prat-Daniel Valmont mechanical collector and a Koppers electrostatic precipitator are in series. The model was constructed of Plexiglas, a methyl methacrylate type of transparent plastic material, and was built to a scale of 1 in to equal 16 in. Experience has indicated that this is a good scale ratio for the purpose and has been used in all of the dust collector system models. The Wagner model (Fig. 1) represents the south half of a symmetrical induced draft system, which is divided at the exit of the boiler and reunited at the stack as shown. The equipment represented by this model handles 218,500 cu ft of gas per min at 289°F at full-load design conditions. By scale effect, this reduced to 860 cu ft per min in the model.

In all of these models, actual gas velocity was used for most observations and measurements. Air was supplied to the model by a blower, and the rate of flow of gas was measured by means of pitot tubes located ahead of the model in a section of duct having uniform gas flow.

Four methods of observation of gas flow patterns in the model were used:

1. Gas velocity traverses were made by means of miniature double pitot tubes.
2. The path of the gas flow and the turbulence were observed visually by smoke patterns.
3. As a further visual indication, fine silk threads on the ends of thin rods were inserted into the gas stream and served as flags to mark flow patterns.
4. To observe the build-up of fly ash in low velocity sections or re-entrainment of fly ash from the hoppers, finely ground cork was introduced into the model. By following the indications of the ground cork, undesirable accumulations of fly ash in this system were avoided.

A simple technique was developed for the smoke trail observations. Dry nitrogen gas was passed through liquid titanium tetrachloride, and the saturated gas was injected into the model at desired locations through small glass tubes. The titanium tetrachloride produced dense white smoke streams which could be followed readily. By means of these smoke patterns, areas of turbulence or reverse flow could be observed readily, and corrective measures applied.

Component Part of Models

Fig. 1 shows a side view of the model under discussion. It consists of six sections:

1. The duct from the air preheater outlets to the mechanical dust collector.
2. The mechanical dust collector.
3. The duct from the mechanical collector outlet to the electrostatic precipitator inlet.
4. Electrostatic precipitator.
5. Outlet duct from electrostatic precipitator.
6. Approach duct to the induced draft fan.

Flow Patterns

With the initial layout, the flow pattern was generally good, but a number of improvements were required to eliminate swirls and to improve gas distribution at several locations (see Fig. 2).

There was evidence that fly ash would accumulate at the elbow near the outlet of the air preheater. This was corrected by a change in shape and by decreasing the duct cross-section in order to increase gas velocity.

The horizontal divergence and skewness of the portion of the duct following the preheater elbow resulted in poor gas distribution at the entrance to the mechanical collector. This was corrected by dividing this portion of the duct into two lanes and installing four vertical guide vanes in each lane. Each quarter of duct then delivered from 23 to 27·6 per cent of the total gas.

The mechanical dust collector consists of banks of centrifugal elements having vertical discharge tubes which terminate in a tube sheet. This tube sheet slopes at an angle of about 24° from the horizontal. It was impractical to duplicate the structural details of the 1,040 centrifugal elements. However, the correct number of tubes was used and small spirals were inserted in each tube to give the exit gas a spiralling effect as in the actual installation.

It was expected that the simple curved duct section between the mechanical collector and the electrostatic precipitator would permit good gas flow, but an unexpected phenomenon occurred. The flow pattern in this curved section showed extreme turbulence which appeared to originate at the gas tube outlets along the tube sheet. The gas did not discharge vertically from the tubes but instead it tended to move along the sloping tube sheet. For a further study of this phenomenon, the curved section of the outlet duct was replaced by a vertical duct of rectangular cross-section, which discharged to the atmosphere. In this substitute duct the gas flow still crowded to one side, although the individual tubes were each discharging about the same amount of gas. About 78 per cent of the gas passed up through that half of the discharge duct which corresponded to the upper half of the sloping tube sheet. For further observation, the whole tube assembly in the model was replaced with a sheet of heavy Plexiglas with holes drilled to represent the tube outlets. The same phenomenon of gas distribution and turbulence resulted.

The results of these tests led to the conclusion that the distortion of the gas flow at the surface of the outlet tube sheet was caused by the relative position of the outlets of the tubes with respect to each other. The indications were that an aspirating effect took place, and that each gas jet in turn drew the jet from the lower tube toward the higher tube. This effect was apparently cumulative; and, with 1,040 tubes, it resulted in a marked distortion of the gas flow towards the upper end of the sloping tube sheet.

To correct this condition, this section of duct was divided into two lanes and four vertical baffles were placed across each lane so as to separate the tubes into five sections of four rows each. It was desired to keep these baffles as short as possible without impairing their effectiveness. Tests showed that this could be accomplished if the tops of the baffles, as shown in Fig. 1, were approximately 2 ft (in actual design) above the elevation of the tube. Even with these baffles, the jet aspirator effect could be observed within each small section. Further improvement in directing the gas stream was accomplished by bending the tops of baffles 20° towards the electrostatic precipitator. These changes, along with some reshaping of the inner arc of the elbow, produced very smooth and uniform flow in the elbow and delivered the gas through perforated plates to the precipitator with adequate uniformity.

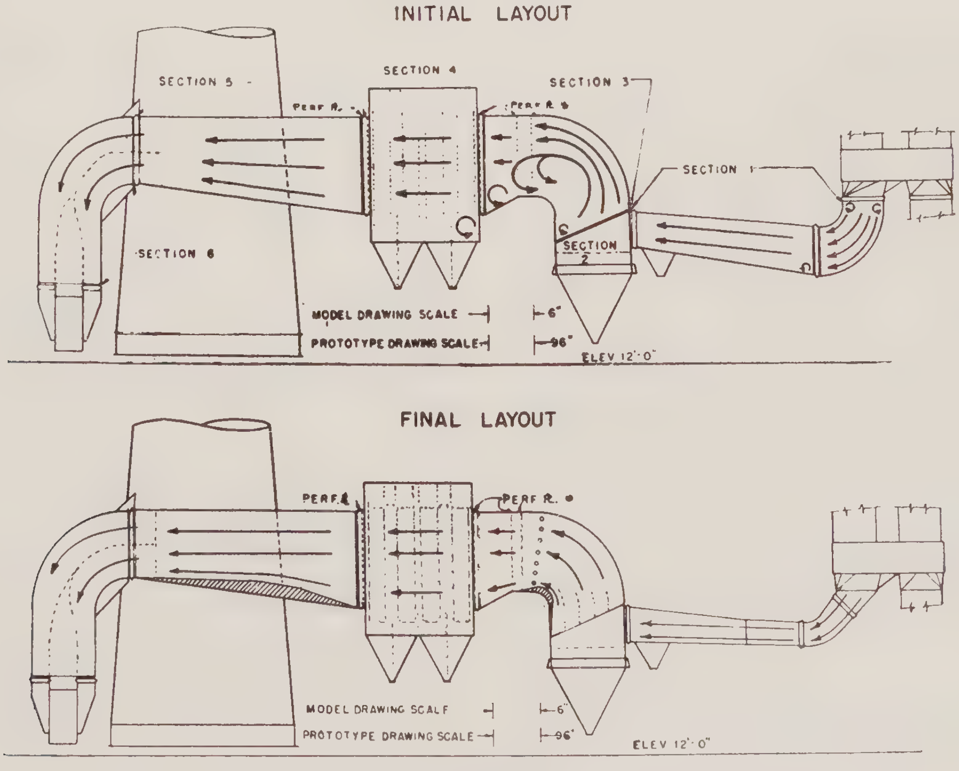

Fig. 2

In the forward part of the electrostatic precipitator, each eighth part of the cross-section carried from 11·7 to 31·1 per cent of the gas. It cannot, of course, be said with certainty that the phenomenon encountered in the model would have occurred in the prototype because of the difficulties of reproducing exactly all of the design details in the model. However, with the changes adopted from the model, good results have been obtained in the actual system.

Precipitator Changes

Although the gas distribution in the precipitator was very good, there was evidence that re-entrainment of fly ash would take place in the first row of hoppers. When these hoppers were filled with ground cork, the gas stream lifted the cork out of the hoppers. This condition was corrected by minor changes in hopper baffles and in the slots located in the lower part of the perforated plates in front of the precipitator.

Precipitator Outlet Duct

Because of the relatively large cross-section of the outlet duct, the gas velocity is low and conditions are conducive to settlement of the residual fly ash. To simulate this condition, ground cork was placed on the bottom of this discharge duct, and the model was operated at full-load gas velocity until the contour of the cork assumed a stable configuration. The bottom of the duct was then modified to follow approximately the outline formed by the cork, and this streamlined shape was then kept clean by the flow of gas. The velocity measurements and smoke patterns were good. When smoke was injected ahead of the precipitator, it was carried through the precipitator and through the outlet duct to the fan inlet in relatively smooth flow lines.

Approach to Fans

Only minor changes were required in the approach ducts to the fan to yield equal gas distribution to the two sides. The horizontal splitter plate had to be raised about 6 in. above the centre line.

Conclusions

Observations of the full-scale ducts and dust collectors under actual operating conditions have shown that good correlation exists between the model study and the prototype.

As previously indicated, the design of a complex gas duct system is an engineering art and not an exact science. Similarly, the authors of this paper look upon the use of scale models as a useful guide and not as a precision device. Frequently, the models reveal phenomena which are readily explainable when seen, but not so readily foreseen. Scale models have been proven to be a valuable engineering tool.

Acknowledgements

Acknowledgement is made to other engineers of the Baltimore Gas and Electric Company and to equipment manufacturers who have contributed to the model studies, described in this paper.

RAPPORTEURS' REVIEWS AND DISCUSSIONS ON THE PAPER

Session II—Legislation and National Problems

Review by Professor A. B. Semple, Rapporteur

Professor Semple said:

In the 19 papers presented to this section by representatives from 12 different nations, we have a comprehensive review of what is going on all over the world to combat atmospheric pollution. Most of the papers come from the highly industrialized countries like U.S.A. (3), Federal Republic of Germany (3), Czechoslovakia (2), Japan (2), the United Kingdom (2) and France (1)—communities in parts of all these countries have suffered the stranglehold of heavy smoke pollution for a century or more. In addition, there are also six excellent contributions from countries where the problem is less acute, but is receiving close attention.

It is generally accepted that the control of air pollution is a local matter affecting the people in a particular area, and therefore, a matter for local government with central government playing a supervisory, and mainly an advisory role. A notable exception to this occurs in Great Britain and is described by Mr. P. D. Coates of the Ministry of Housing and Local Government. In this country a number of industrial sources of air pollution, chemical works, oil refineries, iron and steelworks, power stations and others are not under the control of local government; their supervision is vested in the Central Government Department under the Alkali Acts. These are controlled by a small body of highly qualified Alkali Inspectors working directly from the Ministry of Housing and Local Government. Opinions are divided on whether it is a good thing to have two forms of control for industrial air pollution in one area, namely the Local Authority and the Alkali Inspectorate. Its origin is a matter of history, when the view was taken that local authorities had not sufficient technical resources or knowledge to deal with air pollution from chemical works. Now, history looks like repeating itself in dealing with all radioactive wastes which it would appear are also largely to come in for central control.

In this paper we also have a short account of the more significant aspects of the Clean Air Act, 1956, and an indication of the progress which is being made nationally as a result of this new legislation.

In the three papers from the United States of America, we get a vivid picture of the forthright and determined approach of this country in tackling its black spots of atmospheric pollution. The accounts. of the smoke abatement campaigns in St. Louis and Pittsburgh, together with the description of the local, state and federal control of atmospheric pollution makes stimulating reading. In the paper submitted by Messrs. Tetzlaff and Graber mention is made of the need and the provision in the U.S.A. for establishing a regional authority to ensure air pollution control in a particular area where several local authorities may be involved. This is a point which merits consideration in this country and no doubt elsewhere. The United States' contributions remind us of the importance of open burning of refuse and rubbish, both domestically and industrially, as a source of air pollution which should receive attention.

The three papers from the Federal Republic of Germany show that this country is busily modernizing its air pollution legislation and the government is at present considering a Bill which will take air pollution control out of the public health and factory legal codes and deal with it as a separate entity. As the ascertainment and effects of atmospheric pollution were felt to be of paramount importance, a commission was set up to study and consider the whole subject. This commission, which will become a permanent advisory body, consists of 143 experts! This serves to show the wide range of interests affected by smoke pollution.

In Japan there is no legislation dealing specifically with air pollution although there are certain powers for the prevention of atmospheric pollution in the general legislation and local ordinances in that country. However, there is ample indication that public opinion is now in favour of further legislation, and this has been fostered by much health education on the importance of air pollution control in recent years.

In this connection there is also a contribution by Mr. Arnold Marsh, Director of the National Society for Clean Air in the United Kingdom, which stresses the importance of proper public education. The stimulation of the public imagination on any health topic cannot be done with second rate material. It is not easy to convince a healthy athletic young man that the smoky urban atmosphere in which he lives may give him bronchitis. Then, after years of misery which increases each winter he will die rather painfully in middle age. Yet until we do convince every member of the public that he or she has a duty to prevent this happening, it will be the fate of one man in every ten of our population. To put this message across is vital and it requires work and money—but it must be done. But we must not only preach the dangers of air pollution, we must also teach individuals precisely what they must do to play their part in the anti-smoke campaign. For in the United Kingdom, and to a lesser extent in other countries, the domestic sources of pollution are important in the overall problem. Here the national campaign must have the support of the knowledgeable man on the doorstep—so do not let us forget our greatest educational asset in any clean air campaign—the Public Health Inspector. This may not be quite the gospel according to ' St. Marsh ', but what will have to pass as a free translation of his views.

In the paper submitted by M. Queret, the Secretary General of the French Association for the Prevention of Atmospheric Pollution, he indicates the interest now being shown in that country and the foundation of his Association in July 1958. Once again, public education is the main theme. The French organization has also got groups studying the scientific aspects of smoke pollution and the technical aspects as well as the more general consideration of the problem. The idea of smoke control areas is also going ahead in France.

At this point, may I call attention to the important point made by M. Leclerc of Liège, Belgium, on the part which town planning must play in the creation of clean air in our towns. We note with interest that studies are going on in Liège on the effects of air pollution.

The two papers from Czechoslovakia deal with the world-wide increasing demand for power. In most industrialized countries the demand for power is largely met by the combustion of coal and to a lesser extent by oil. In these papers the modern widespread burning of coal of inferior quality gets a special mention. Wherever these volatile sources of power are used an air pollution problem exists and must be tackled, especially in the face of the growing need for power which is linked to a rising standard of living. Again in Czechoslovakia, much measurement is carried out, and as a result an extensive programme of industrial air pollution control is being pursued. In certain areas main electrical power plants and industrial processes have been redesigned to use natural gas. But in many areas heavy air pollution persists, which has been shown to have an effect on the health and development of children. Considerable losses have also been shown to occur in agriculture, forest-culture and other similar activities. The control measures include, in addition to the removal of solid pollutants, gas washing plants to remove the sulphur oxides from the flue gases of coal burning power stations.

Next let us look at the papers from the less industrialized countries—Norway, Sweden, South Africa, Switzerland and the Republic of Ireland. Public interest has been stimulated because the smoke nuisance is an increasing problem, and the annoyance and discomfort is being added to by the effluents from chemical factories, oil refineries and other industrial processes. Domestic air pollution is of minor significance. These countries have set up *ad hoc* committees to investigate the sources of air polution and recommend abatement legislation for its control. Dr. Halliday of South Africa stresses once again the importance of the association of public education with legislation. Mr. Lindberg from Oslo, Norway, reminds us of the fluorosis hazard in cattle owing to pollution of grass in pastures near aluminium plants, and Professor Brosset and his colleagues indicate some of the active research on air pollution going on at Gothenburg, Sweden. Even in a delightfully clean country like Switzerland there are public complaints about odorous air pollution although smoke can be practically disregarded. Our Irish contributor, Mr. Dawson, gives us an account of the legislative pattern which he considers practical for a small not too highly industrialized country. He also stresses field staff as educators.

The sessional papers considered in these two broad groups—the highly industrialized countries, and the not so highly industrialized countries—give a fairly complete picture of all the aspects of air pollution confronting governments throughout the world.

Furthermore, there are one or two novel ideas mentioned. The contributors from the United States, you will recall, mentioned the need for regional control and the importance of the smokelessness of refuse disposal. In addition, Mr. Schreibeis and Mr. Carter in their papers also mention the use of the measurement of reduced visibility records as a measure of atmospheric pollution. This seems a measurement which should have considerable public appeal. There is also in a number of the papers a considerable interest in the control of fumes from road vehicles and some suggestions for legislation on this subject. If the day of an exhaust gas device for internal combustion engines is at hand, it will be a great stride forward in the clean air campaign, especially in our cities.

We have come a long way in the last 60 years, and the greatest enemy to clean air—public apathy—has been overcome although not completely vanquished. We have the knowledge to reduce substantially the air pollution in our countries to such a level that it is no longer a menace to health and community life. We must find the means and the methods to apply that knowledge.

Discussion

J. O. Buxell (World Health Organization) in opening the discussion said that it was of great interest and quite a privilege to represent the World Health Organization. Obviously the papers at that session represented a number of countries of the world, and perhaps a good sampling of the national programmes for the control of air pollution in the countries of Europe. He was impressed first in the general review of papers with the similarity of conclusions that could be drawn from them to those that were drawn from a somewhat similar international conference held at Milan in 1957, under the sponsorship of W H O , and which covered the public health aspects of air pollution. The similarity arose out of a number of concepts put forth in those papers. The one that he wanted to stress first was the fact that the authors collectively seemed to point out rather emphatically that air pollution was a very diverse subject—that it was not simple and could hardly be generalized. If the papers were reviewed it would be seen that much more than one type of air pollution was covered, although a number of the papers did refer to the problem of smoke as a source of air pollution, or as a part of air pollution. One would find many other types of air pollution stressed in the papers and for differing countries the various types of air pollution were of major importance to them. It was brought out that the study and the control of pollution generally was one which was in a sense to be tailor-made for localities, for regions and for nations.

Two of the papers from the United States, which represented the effects of air pollution control in two cities—two cities that could be said to have earned in the past the unenviable reputation of possibly being two of the dirtiest cities in the world—St. Louis and Pittsburgh. Mr. Buxell said that he had been personally connected with the City of St. Louis smoke control effort and he thought that that paper brought out the point of diversity of air pollution activity and sources. Mr. Carter had mentioned the fact by legislation and the enforcement of that legislation it was arranged to secure the use of smokeless fuels, or the burning of high volatile non-smokeless type solid fuels by the use of mechanical means, and therefore smokelessly. This measure after its enforcement was extremely successful in reducing the amount of sootfall, a major component of smoke nuisance. But it was soon realized that there was another aspect of smoke pollution, an aspect of grit production, which arose primarily from the use of pulverized coal, fired mechanically, and a different type of approach had to be made for those kinds of sources of air pollution. It finally ended up with the identification of the sources and the use of electrostatic precipitator collectors. In addition the solution of that problem revealed more clearly another type of problem which was the sulphur compounds from the burning of fuel. Fortunately the authors of the legislation had provided in the legislation a requirement that high sulphur type fuels would have to be reduced in their sulphur content through air or water washing. That did achieve a considerable amount of reduction of the sulphur compounds in the atmosphere. However, it was not a complete success, the sulphur compounds were originating not only from fuel, but were originating also from chemical and other industrial type plants. These raised the questions of identifying the source, proving excessive quantities of air pollution released and eventually controlling this through some effective collection or prevention method.

Mr. Buxell stressed this primarily because he believed that the papers did demonstrate, and this was a conclusion which came out of the Milan Conference as well, that the air pollution problem in European countries particularly was not a set one and was one which had to be investigated on the basis of national, regional and local control. A second conclusion that he saw in the papers was that there was a great deficiency of epidemiological evidence of a convincing nature that air pollution did affect public health, and this kind of evidence was probably the most effective type of evidence which they generally need to promote the control of air pollution.

The Milan Conference, and probably arising out of the present and perhaps further discussion in later sessions, would again reach the conclusion that more information on these subjects was needed. There were some indications of specific types of air pollution which caused specific types of illness and disease, but the generalized type of relationship was still not convincingly demonstrated. Again they were seeing a breakthrough of science on the question of the relationship of cancer, lung cancer particularly to industrial air pollution, and would probably be able to demonstrate statistically a certain relationship in the question.

Another thing which was apparently evident in the papers generally was the question of legislation. The Rapporteur had dwelt on that, particularly discussing it from the standpoint of local authorities, from the standpoint of special agencies, from the standpoint of regional control and ultimately types of centralized control.

Mr. Buxell was impressed by at least four of the papers from four of the countries represented, that in those countries they are still looking for the ideal type of legislation. They were hoping for improved types of legislation for the control of air pollution. He thought this was a demonstration that there was still a considerable need for what might be called experimentation or trial of different forms of legislation for the effective control of the problems.

The papers also stressed in their total the very great importance of an educational approach to the prevention and control of air pollution. Not only the education of the public, to support legislation or to cause the production of effective legislation, but also the education of the public to accept the type of regulation that was necessary effectively to control air pollution in its various forms, to understand those needs and to apply them. There was also evidence in the papers that education must proceed on an individual basis for many of the persons who were key factors in the question of air pollution. They had indications of the Public Health Inspector and his training, the question of the boiler operators and certainly of the designers and planners of such type of construction and equipment as would prevent or control air pollution.

Finally there was indication in the papers for the need for further research and for international action. He thought there were at least four papers in which suggestions for international type action was made. He believed that they would have in a further session a chance to discuss those and he was sure that his organization—the World Health Organization—would welcome any ideas, suggestions, recommendations and concrete plans for carrying out that type of co-operation.

Councillor C. Evelyn Gough (Caerleon U.D.C.) addressed the conference on the question of diesel pollution to the effect that no serious attempts had been made to check excessive diesel fumes from vehicles, much of which resulted from poor or non-existent maintenance of lorries and buses. He asked Mr. P. D. Coates of the Ministry of Housing and Local Government what his Ministry proposed to do about the modern version of the " Puffing Billies " which are cluttering up our highways, in the form of diesel driven vehicles belching forth diesel fumes indiscriminately.

Councillor Gough suggested that amendment of the legislation dealing with offenders was long overdue.

Dr. W. R. Martine (Administrative Medical Officer of Health, General Purposes, City of Birmingham) said that he did not wish to introduce a discordant note but sought an answer from Mr. Coates to a very pressing question.

The *Municipal Journal* of May 22, 1959, had described the Annual Report of the Chief Alkali Inspector as a " sorry tale of inadequacy ".

The supervision of certain industrial processes had been taken from local authorities because their officers were not held, by their training ,to be fitted to supervise them. Yet much of the time of the existing inspectorate had been devoted to the training of new staff: that hardly fitted in with the reason given for removal of responsibility from local authorities.

The report stated that the time spent in training this new staff of four assistants resulted in a curtailment of the work done by the inspectorate and yet the Chief Inspector rated the organization as " showing every sign of being an able and efficient inspectorate ".

But was it an adequate inspectorate?

Could the conference have any explanation as to why trained men could not have been appointed in the first instance, and, further, some assurance that an adequate number of inspectors would soon be appointed and that the work, formerly a charge upon local authorities, would be carried out with an efficiency at least comparable with that of local authority officers?

Councillor C. A. Watson (Scunthorpe Borough Council) said that Scunthorpe was a town of 60,000 population, where approximately 2¼ million tons of steel and 2 million tons of iron were produced each year. This involved the mining, crushing and preparation of more than 1½ million tons of local ore, the crushing and preparation of 1 million tons of Northamptonshire ore, the carbonization of more than 1 million tons of coal and the crushing of several hundred thousands of tons of slag.

In the town, as in most other industrial towns, there were two aspects of the problem—namely domestic smoke and industrial pollution. In respect to the former progress was reasonably simple to measure and for the latter one ought to expect to be able to assess progress from the annual report of the Chief Alkali Inspector.

In his opinion the annual report for 1958 of the Alkali Inspector was an extremely disappointing document. He accepted that the facts recorded therein were true. In his judgement, the document was so cliché-laden and the emphasis so over-stressed as to difficulties encountered, that as a yardstick to measure progress it was completely valueless.

On page 6 we were informed that authority was given in 1957 for the appointment of 12 additional inspectors, but only four had been appointed at the time of the report. If it was remembered how few inspectors were employed when the Act was passed and remembered the enormous additional work devolving on the inspectors, the recruitment of only four inspectors was pitiful.

He said that, as regards pollution caused by the iron and steel industry, dealt with on pages 28, 29 and 30 of the document, only a statement of the difficulties met with in the various processes were mentioned. In this statement, on open hearth furnaces, page 29, the view expressed that the new technique of tonnage oxygen usage was likely to make such furnaces obsolete, was a reckless statement having regard to the highly successful processes recently evolved by the United Steel Co. by the adaptation of two open hearth furnaces in Scunthorpe and to the increased tonnage produced by these furnaces.

He expressed the firm conviction that at succeeding annual conferences efforts should be made to give to delegates a progress report. In so far as domestic pollution was concerned that would be relatively simple, but that it might be better to give the figures of units of conversion to smokeless fuels rather than acreage of smoke control areas. In respect to industrial pollution covered by the Alkali Acts, the Alkali Inspector's annual report should be regarded as a yard-stick showing progress. Indeed, he strongly urged that the Alkali Inspector's report for each year should be placed on the conference agenda for discussion.

He believed that if this was done, delegates could make critical and constructive comment on the report, both as to the matters contained in it and, what was perhaps equally important, on what was left out. He could not believe that the absence of specific reference to inspections, etc., relating to Clean Air problems was accidental but instead was a camouflage to hide the absence of any effective action.

Councillor Watson said that he sincerely hoped that the Council of the Society would give the matter their serious attention.

Councillor W. A. N. Jones (Birmingham City Council) said that the Minister had said to the conference, and rightly so, " that vigorous implementation of the Act will bring success ". But how could those in local government do that, when they found the relationship between them and the Alkali Inspectorate a not very happy one? They found that the words in the Alkali Act clauses, " best practicable means " could be used as an escape from responsibility. Local authority elected representatives and officials found grave difficulty in explaining away complaints of nuisances from air pollution caused by industrial processes covered by the Alkali Acts. Therefore, the future must provide for a new look at ways and means of a more effective liaison, or even by giving large authorities such power as was now invested in the Alkali Act Inspectorate.

R. M. Drummond (Drummond Patents Limited) said that his remarks were in the nature of an appeal rather than criticism.

Many of those who had spent the last 25 years investigating the matter of atmospheric pollution knew that British industry was most well disposed and many most ready to spend money on installations to rectify any pollution that they created from the processes of their business, although the expenditure did not become a normal asset on their balance sheet.

There was, however, a strong retarding influence existing to that end. That could only be set aside by the Government itself. It was the absence of a " yard-stick " of tolerance which if clearly stated would bring the industries, the pollution prevention plant manufacturers, and the Government Inspectorate into such a common ground of definite understanding that a tremendous acceleration of country-wide achievement would be experienced.

To achieve that it would be desirable that a broad cross-sectional study of industrial effort to deal with pollution be carried out by Government controlled tests throughout the various manufacturers of dust extraction equipment, without prejudice or favour to any particular type or design. The Government would then have a cross-section of the achievements of industry in that service today.

Mr. Drummond further suggested that a probationary period of, say, five years be given under this declared tolerance, after which the matter could be reconsidered in the light of further industrial progress that might then have been accomplished.

In addition to the Ringelmann Scale a grain percentage per cubic foot of impurities, incorporating particle size and allowable acidic content of exhaust gases, should be declared.

Under those conditions industry could reasonably and with confidence ask contractors for guarantees and the manufacturers could comply with their request.

G. W. Farquharson (Chief Smoke Inspector, City of Birmingham) said that in the Birmingham area observations carried out by the specialized smoke inspectorate during recent years indicated a considerable improvement in the emissions of smoke from steam raising and some process furnaces such as annealing and reheating of metal, unfortunately, the same improvement had not been noted from the chimneys serving processes now under the umbrella of the Alkali Acts.

On paper No. 2 " The Planned Investigation of Air Pollution in Gothenburg ". It was interesting to note the intention in Sweden of carrying out a pilot survey on the effects of air pollution on selected patients suffering from chronic bronchitis. Using this respiratory condition as a yard-stick should prove a most interesting investigation, and furthermore, the results could well be utilized to convey to the public the effects of such pollution on persons suffering from a common ailment.

In paper No. 3, Mr. J. H. Carter of St. Louis, Mo., U.S.A. referred to the St. Louis Ordinance by which a maximum chimney dust loading was regulated. Section 7 of the Clean Air Act, 1956, whilst providing powers for the Minister to prescribe by regulations the measurement of grit and dust from furnaces, did not indicate the possibilities of specifying a permitted maximum chimney dust loading. It appeared to Mr. Farquharson that future legislation in the form of regulations specifying such a maximum loading would be an excellent guide for the manufacturers of dust arrestation equipment, and also for industrialists when ordering such equipment to comply with certain specifications to meet a legal requirement. Furthermore, such a permitted maximum loading figure would be of great help to local authorities when carrying out the provisions of Section 5 of the Act which relates to the requirements that grit and dust from furnaces shall be minimized.

Mr. Farquharson said he would be pleased to hear Mr. Coate's comments on this line of thought.

W. H. Wattleworth (Chief Public Health Inspector, Liverpool County Borough Council) stated that although he was following Birmingham on the rostrum, this was entirely coincidental. He was rather concerned that the tentative legislation which had now been enforced for three years required considerable stream-lining and the time had arrived when consultations should take place between the Ministry and those engaged in the field. There were many aspects causing concern and difficulties in administration of the appropriate sections. The individual approach had proved successful in solving the industrial problem, but the domestic problem was being tackled by some form of mass formula.

Before a Smoke Control Order was confirmed and in operation the following stages had to be accomplished:

1. General survey of the area
2. Submission and report to the Health Committee
3. Confirmation by the Council
4. Submission to the Ministry for preliminary confirmation
5. Preliminary confirmation
6. Detailed survey
7. Confirmation of the Order
8. An interval of at least six months before date of operation.

Throughout this procedure there was a stream of correspondence and the possibility of a public inquiry to delay the procedure even further. Therefore before a Smoke Control Order was operative at least 12 to 15 months usually elapsed and if the amount of time devoted to the survey was added, then two years was a minimum.

Large local authorities had to think in terms of 20,000 to 30,000 houses annually and even at this rate, it would take 10 to 15 years before any appreciable effect was seen in the domestic problem. The survey was a hazardous undertaking, having to be carried out with an inadequately trained staff, and the department dislocated for a period of at least six months, and these difficulties gave rise to irritation.

The first survey usually only completed about 25 per cent of the houses visited; then after casualties had been counted, i.e., staff protests, etc., then those houses where the occupiers had not been downright rude were visited. A further percentage was then obtained leaving a hard core of some 25 per cent where occupiers were unco-operative, which included door-slammers or smoky coal worshippers. When the survey was finished, as far as possible, there was usually some 200 houses with apparently no life at all despite signs of occupation, such as milk left on the door step in the mornings. These had to be visited either before the occupants had left for work between 7 and 8 a.m., or late at night just as they were ready to go to bed. Delegates could easily imagine the scene when people were roused from their beds in the early morning, or late at night, to discuss a change of firegrate, particularly if they had been using electricity for the last three years!

There were many thousands of houses in the country where the occupants were—

1. " Wanting to convert ";
2. " Willing to convert ";
3. " With a suitable house to convert "; and
4. " With the money to convert ".

But unfortunately these enthusiastic people could not do anything until the Order was confirmed and the date had been passed by the Ministry.

Mr. Wattleworth said he could understand that some form of control was necessary having regard to the fuel requirements, but individual relaxation should be considered. The speed of smoke control was now dictated by a small minority of objectors, for to satisfy that small group, lengthy procedure was apparently required. Thousands of co-operators all over the country were waiting for a lead, and therefore full advantage should be taken of this good will before there was a waning of enthusiasm. Mr. Wattleworth hoped the Ministry's representative would consider this plea from overworked officials who were finding the administration of smoke control a heavy task.

Professor E. R. Kaiser (University of New York, U.S.A.) said that he suspected that the chairman had wanted to " get the heat off " the Alkali Inspectorate for a little while and had therefore called on him. He brought greetings from the United States and said that the limited attendance from the States was no indication of the wide interest held there in the success of the conference.

Mr. Schreibeis had mentioned two items which had to do with incineration and Professor Kaiser believed that they should be given a little more consideration and thought that they would be in future years. This was said not to distract in any way from all the other problems such as coal smoke, SO_2 and other aspects which were treated quite heavily in the conference programme. However, on the subject of refuse incineration he said that in multi-storey apartment buildings their problem was one of getting rid of about $1\frac{1}{2}$ lb of material, including paper, tin-cans, wire coat hangers, glass bottles, and so on, per capita day.

A central incinerator in the basement is used which is charged by dropping refuse into chimney through hoppers at each floor level. The porter then burned refuse, the gases and some dust being discharged through the same charging flue. In a large city those flue-fed incinerators were a source of air pollution, on the other hand they reduced very considerably the amount, the tonnage and the bulk of refuse that must be hauled through the streets. With the traffic at least as congested as in New York or London anything that could be done to reduce the number of motor-vehicles, trucks and so on on the highways is a big help.

These flue-fed incinerators reduced the weight of the refuse to about 35 per cent, not that there was so much ash in it, he said, but that the tin-cans and bottles added quite a bit of weight, however the bulk (volume) was reduced to about 10 per cent. In the United States they used an enormous amount of paper, which was very bulky, especially by the time it got down the chute into the incinerator. As the result of a research programme supported by their national U.S. Public Health Service, reductions in emission up to 90 per cent had been demonstrated with practical equipment. By the use of over-fire air jets in those incinerators, they could speed up the burning and improve the combustion considerably. A still better job resulted by burning gas as auxiliary fuel in the furnaces in order to heat up the gases and to provide radiation which would accelerate the burning and bring the temperatures up well past the ignition point of the fats and carbon particles given off by the otherwise smouldering fire. The best results, however, from an air pollution standpoint, and those were very satisfactory, were by the use of a scrubber to clean up all of the gas before it was discharged out the top of the chimney.

The other thing which might be new to some of the delegates—which might indicate a trend and was still rather new to them for that matter—was the burning of automobile bodies. Mr. Schreibeis had mentioned this problem. They used up about 4 million automobiles and buses a year in their country. In order that the steel be converted to a form that could be used by the steel companies and put back in the open hearth furnaces, for example, the simplest way was to burn the body after it had been stripped of the copper radiator, the lead battery and so on. That was usually done in the open; a car would burn very rapidly especially after a little gasolene or oil on the upholstery would set it off in good order. Now, open burning process made a great deal of smoke (not much fly-ash however), but by burning the cars in brick-lined chambers or even in a concrete pit and subjecting all the gases to additional heat from an oil-burner or a gas-burner to make sure that the gases exceeded 1,500°F, the smoke was eliminated. Professor Kaiser reported that the steel was cleaner as the result of closed burning than with open burning, in that the combustion of paint, undercoating and plastics job was a little more complete on the steel itself, and lead and solder and so on dripped off. Again some research was needed because often the small scrap dealers who had been doing the open burning, and were now prohibited from doing it in New York, didn't know how to equip to do the job. On a big scale Professor Kaiser dealt with one plant that burned 25 cars an hour; that could be a continuous production device and by the means he described a good job could be done in batches of one or two cars at a time, in a rather modest furnace and not too high a stack with a rather simple oil burner. He understood that British cars had to go back to the steel mills in baled form just as theirs did and that not so much burning was done. He predicted that Britain would be burning her cars and she might find that they were being burned in the open. If the results of this auto-body incinerator, which had been developed and demonstrated in the United States, was of interest to delegates Professor Kaiser said he would be glad to supply them with information.

G. Ainsworth (Chief Public Health Inspector, Ripley Urban District Council) in a written contribution, said that during the post-war years discussions on domestic fuel and its relation to clean air had produced many comments on the very vexed question of miners' concessionary fuel. Representatives of Clean Air Joint Consultative Committees and of the Miners' Unions in various parts of the country had discussed this matter. Unfortunately up to date no solution had been found. He, therefore, desired the author of Paper No. 1 (Mr. Coates of the Ministry of Housing and Local Government) to be so kind as to express his opinion on the practicability of the following suggestion:

> In view of the fact that the majority of the suitable smokeless solid and other forms of fuel were manufactured and marketed by various nationalized undertakings, would it not be a pure mathematical problem for an agreed British Thermal Unit figure to be arrived at for the thermal value of the concessionary fuel? The member of the mining industry would express a written option for a particular type of fuel, i.e., coke, gas or electricity, therefore by arrangement with the other undertakings for that individual to receive the identical heating value of an alternative specified fuel. By this means an individual would not suffer any monetary loss and the nation would achieve efficient use of fuel; a contribution would also be made to a cleaner atmosphere.

W. D. Jarvis (Central Electricity Generating Board) said that Professor Semple had referred to emissions from Clarence Dock Power Station, Liverpool, as being a cause of complaint, and he would like to assure him that every effort was being made by the North West, Merseyside and North Wales Region to prevent the chimney emissions from being troublesome to the neighbourhood. A working party had spent considerable time in investigating boiler operation and it should be noted that the boiler plant was installed about 22 years ago by the City of Liverpool Electricity Department. In a wider sense the Central Electricity Generating Board were carrying out intensive surveys of atmospheric pollution around 56 power stations.

Professor Semple had also made reference to the use of flue gas washing in Czechoslovakia in a paper presented by Mr. J. Polacek. He suggested that only in this country, at two power stations operated by the Board, were flue gases being washed to remove the sulphur oxides content.

Author's Reply

P. D. Coates (Assistant Secretary, Ministry of Housing and Local Government), replying to the discussion, said that at an international conference too much time could be devoted to matters of internal British administration of little interest to overseas visitors. The criticisms made of the Alkali Inspectorate demanded some reply, but he would try to be brief.

First, suggestions had been made that control over smoke, grit and dust emitted by processes under the control of the Alkali Inspectorate would be better dealt with by local authorities. That was contrary to the recommendation made by the Committee on Air Pollution under the chairmanship of Sir Hugh Beaver, the President of the National Society for Clean Air, and but for Sir Hugh's regrettable illness the conference would no doubt have had the benefit of his comments on these suggestions. Paragraph 45 of the committee's report had stated: " We have heard no serious criticism, and a great deal of praise, of the system of control in force under the Alkali Acts and of the results achieved. We are satisfied that this system, under which processes are registered, and supervision and control follow, exercised as it is by an experienced technical inspectorate, constitutes the means best calculated to apply a continuing challenge to, and exert effective supervision and control over, those industrial processes which present technical difficulties in the prevention of dark smoke, grit and dust." This recommendation had been accepted by the Government of the day and approved by Parliament.

Secondly, the Chief Alkali Inspector's Annual Report for 1958 had been quoted as evidencing an inadequate intake of new Inspectors. The effect of the Alkali, etc. Works Order, 1958, had been to treble the number of works coming under the Inspectorate. The alternatives before the Inspectorate had been either in the first instance to take in and train a relatively small number of additional qualified chemical engineers and fuel technologists and at the same time to continue the Inspectorate's work, or to take in a large number at once and to divert all the Inspectorate's energy to training the new staff in their administrative duties under the Alkali Act. As his report stated, the Chief Inspector had followed the first course. The intake and administrative training of technically qualified staff was continuing and so was the normal work of the Inspectorate.

Thirdly, it had been suggested that the Alkali Inspectorate was moving too slowly in curing the air pollution problems presented by the new processes brought under them by the 1958 order. It was perfectly true that progress was slow. The technical problems were difficult; it was precisely for that reason that the processes had now been brought under the Alkali Inspectorate. These problems were now for the first time being systematically examined. To examine them the Chief Inspector had set up numerous working parties with the industries concerned. There could be no easy answer and it would be quite wrong to expect an overnight improvement. Nevertheless a line was now for the first time being pursued that would eventually solve problems which previously were not being tackled at all. In the interim period the alternative to tolerating some degree of air pollution from these processes was to shut down the industries completely, an alternative which could hardly be seriously considered.

Finally, it had been suggested that the Chief Inspector's Annual Report was a document which deliberately camouflaged the true position. The Department could not for a moment accept any suggestion of that sort. The report was a factual record of the Chief Inspector's proceedings which he was under a statutory obligation to make annually and which was by statute annually laid before both Houses of Parliament.

Referring to Mr. Wattleworth's remarks Mr. Coates said that the administrative procedure introduced after the passing of the Clean Air Act, 1956, had necessarily been tentative. Now that practical experience of its operation had been gained the time had probably come to review the procedure in the light of that experience, and his Department certainly did not claim perfection or finality for existing procedures. But in order to avoid objections when smoke control orders were made close contact with the persons affected before orders were formally made seemed highly desirable. While therefore a house to house survey obviously meant a good deal of work it might perhaps have compensating advantages by eliminating potential objections.

As regards other matters raised, the emission of dark smoke of any appreciable density from diesel-engined vehicles was due to faulty adjustment, careless maintenance or wrong driving and could be almost entirely eliminated by correct maintenance and operation. It was alreadv an offence under the Motor Vehicles (Construction and Use, Regulations, 1955, for vehicles to emit harmful or dangerous smoke on the roads. The enforcement of these regulations was the responsibility of the police but they were made by the Ministry of Transport who were considering what could be done further to assist the police and to improve the general standard of maintenance and operation.

Standard specifications for apparatus designed to measure smoke, grit and dust emissions and standard colds of practice for carrying out measurements were now under consideration by the British Standards Institution.

The National Coal Board and the National Union of Mineworkers were discussing ,on a national basis, the question of supplying solid smokeless fuels (including coke) to mineworkers, and the average value that should be placed on existing allowances of concessionary coal. He could not say that the value would be expressed in terms of thermal units, but the importance to clean air of some value acceptable to both sides being agreed on was undeniable.

Session III—Technical Contributions

Review by Mr. G. Nonhebel, Rapporteur

Mr. Nonhebel said:

G. H. Daniel has given us a masterly survey of the probable growth of world demand for energy arising out of $1\frac{1}{2}$ per cent per year growth of population. During this century industrial production has grown at a compound interest rate of over 3 per cent per year, and the use of primary fuel at over $2\frac{1}{2}$ per cent per year, with a greater rate during the last ten years. By the end of the century, it is predicted that energy requirements will be trebled.

Fuel is steadily deteriorating in quality. In Britain and the U.S.A. the sulphur content of coal increased from 1·3 to 1·7 per cent during the last 20 years; similar deterioration is reported from Germany. Again, the sulphur content of residual oil has now risen to 3–4 per cent depending on the source.

To add to the embarrassment, we are getting bigger towns and bigger factories with increased local emissions both from fuel furnaces giving more sulphur and dust, and from motor vehicles giving CO from petrol and dirt from diesels.

The saving graces are natural gas from which sulphur is removed; electricity is now three times cheaper in relation to coal than before the war and we shall get nuclear power. Also less and less coal is being used directly in factories and homes, replacements being by the secondary fuels, electricity, gas and coke. It should be noted that nearly all the large power stations are now being built outside towns.

The paper concludes that more sulphur recovery is required. Dr. R. Lessing examines in detail the problem of sulphur. He reminds us that half the sulphur in coal could be removed by adequate cleaning, but the remaining sulphur which is present in a chemically combined form with the coal substance cannot be removed. Dr. Lessing would like to see erected special power stations for burning colliery refuse containing the discarded sulphurous fractions removed from coal, and treatment of the resultant flue gases. The higher the sulphur content of the flue gases, the more likely it is that an economically satisfactory process can be developed.

Dr. Lessing laments the fact that papers on the progress of removing sulphur from residual fuel oils have not been published. He concludes by stressing the need for intensive research, coupled with inventiveness, to evolve a system for the dry removal of sulphur from the flue gases. Dr. J. Bronowski reports the striking fact that the public is buying more premium fuels despite the higher cost per household. In percentages, it is premium fuels for open fires which have shown a greater increase than sales of oil to households. He then goes into a discussion of requirements. The average British person wants open fires without special grates—they want flames, quick pick-up, good radiant heat, low ash and dense fuel and lastly no smoke. The National Coal Board have now decided to go into the manufacture of smokeless processed fuels for the domestic market. This is an important and highly significant change in policy. Two new dense fuels are being developed which have the high volatile contents of 25 and 35 per cent but are nevertheless smokeless. At present only pilot plants are being built to test public demand as the fuel will be more expensive than coke. In the meantime expedients will be used to produce adequate reactive coke in old ovens.

Weinberg and Randall of the National Coal Board state that energetic action is (at last) being taken to supply more consistent coal, lower in fines, to small industrial plants and claim that, with modern equipment, it is possible to have automatically controlled smokeless high efficiency plants. Most small coal-fired industrial plants are outmoded, dirty and inefficient. A list is given of 20 well-run plants of which six are approved for Smoke Control Areas. The owners have agreed to a request by the National Coal Board that these plants should be available for inspection by any industrialist. It is not stated whether any of the plants are automatically controlled. They conclude by stating that coal can compare with other fuels in cost and amenity; there can be serious troubles with oil.

The necessity for training courses for firemen is emphasized by S. N. Duguid in his paper and he mentions the success of correspondence courses.

One of the problems of oil-firing, particularly of small industrial boilers and the large boilers in commercial buildings, is the emission of acid laden smuts.

B. Lees shows that most of these arise from cold flues and chimneys and he describes an inexpensive and technical method of jacketing chimneys to keep them warm.

A problem that has come very much to the fore in recent years is the elimination of the brown fumes of very fine iron oxide which are blown out from steel furnaces where oxygen is used instead of air to purify the molten metal and convert it to steel. Use of oxygen cheapens the process of making steel. K. Guthmann gives an account of the programme of technical investigation on dust removal which has been prepared by the European Coal and Steel High Authority. This is a four-year programme which includes the problems of oxygen steel making. In his other paper K. Guthmann states that the problem of removing the dust from the brown fumes from one of the steel-making processes, namely the Austrian process known as the Linz-Donawitz, may be regarded as solved either by electrostatic precipitators or by Venturi scrubbers. The capital cost of the latter is much lower than that of electrostatic precipitators.

P. Lasserre describes the methods to be employed in designing hoods to collect fumes from all kinds of furnaces and other apparatus. He emphasizes that much money can be wasted and ineffective results obtained when collecting hoods are badly designed. The collecting hoods, of course, are trunked to an appropriate gas cleaning plant.

The other problem of the iron and steel industry is that of black smoke from low temperature furnaces for reheating billets and bars and annealing semi-finished articles.

Research investigations at Sheffield University on the mechanism of smoke formation in these furnaces indicate that it is not necessary to have a smoky atmosphere in the furnaces but that if a furnace is used in which smoke is made, it is important to prevent the volatile matter from the coal bed passing through regions of high temperature—if this can be achieved the smoke is much easier to burn. The investigations are not complete and no description is given in the paper of any results on full-scale furnaces.

Smokeless operation of coke ovens is one of great technical difficulty and consequently the 70 coking plants in this country have been placed under the supervision of the Alkali Inspectorate. R. L. Cooper describes the progress that has been made and one of the most important points in his paper is that there is a joint working group of the Alkali Inspectorate and the industry to study progress that is being made in the solution of the problems. Some progress has been made by better design, improved maintenance and more careful operation, but a coke oven plant cannot yet be installed in the middle of a housing estate.

R. F. Hayman gives examples of industrial process plants which have been converted from coal to gas-firing with economic advantage as well as complete abolition of smoke and, because gas is desulphurized, elimination of discharge of sulphur oxide. Clearly, the technical service provided by the British gas industry to manufacturers is a benefit to both themselves and the local population (except that some gas is made in coke ovens and these have their problems).

J. W. Jacquest of the staff of one of the big manufacturers of diesels repeats that there is no need for black smoke from diesel vehicles if only the engines were more frequently checked and maintained. It does appear, however, from his paper that maintenance of diesel engines is not as simple as that of petrol engines to avoid smoke and that special equipment and properly trained maintenance men are required. Some of such equipment is on view in the exhibition. These facilities are available to operators of large fleets of diesel vehicles, but the paper does not make it clear whether the required information as to training is percolating down to the smaller garages which service the lorries operated by small transport companies.

Discussion

Dr. W. C. Turner (Medical Officer of Health, Metropolitan Borough of Poplar) in opening the discussion reminded the meeting that the conference was international and that this was a technical session; out of respect to overseas delegates the meeting should refrain from parochial polemics and try to keep the discussion at a high technical level. As scientists they must be critical in this interpretation of data obtained from experiment and particularly in the explanation of observed phenomena not readily capable of being reduced to numbers.

Many interesting points had been introduced in a number of excellent papers. There was a survey showing the growth in the world demand for energy and the possibility of the removal of sulphur from flue gases by a dry process.

Coal was a valuable raw material and it was quite inexcusable to convert its chemical potentialities into a serious nuisance. In Czechoslovakia the best grades of coal went to the chemical industry and only inferior material was used for fuel but that introduced another problem from the high ash and dust content of flue gases.

The research in dust removal had shown that with high space charge density of ions in the gas, electrostatic precipitation was extremely efficient. They were fortunate in having the Director of Process Development of the National Coal Board present and they might ask him for a word on the future policy of the Board in the production of solid smokeless fuel. Research has shown that the removal of 15 per cent of the volatile component from a 40 per cent bituminous coal provided a reactive low ash char which burned smokelessly. Unfortunately there was a paradox in that the coking process itself could not be operated smokelessly.

Attention was drawn to the enormous possibilities of the use of gas in various industries as the fuel of choice.

An analysis of the cause of serious nuisance from brown fume in oxygen blowing steel works showed that more than 80 per cent of the spherical particles were less than 0·8 microns and there was tremendous heat loss in the waste gases which had a temperature of up to 1,800°C. For economical projects it was necessary to recover waste heat from dust collected by a wet process controlled so that the final electrostatic precipitation was on a dry gas. Dust removal in collieries, iron ore mines and metallurgical industries had been the subject of four years' study in combating silicosis.

The Chief Medical Officer of Brussels suggested the de-sulphurization of petroleum products, the use of sealed units on automobiles and replacement of the petrol engine with its high carbon monoxide in the exhaust by oil engines, and one must not forget the diesel engine was originally devised as a safe means of motive power underground in mines; attention has been drawn in another paper to the importance of maintenance not only of metering and injection equipment but also of maintaining compression.

Attention was drawn to the emission of acid smuts as a special type of pollution associated with residual oils used as fuel. These fuels contained a high percentage of sulphur and inevitably there would be a higher content of sulphur dioxide in the flue gas. Under certain conditions up to 5 per cent might be oxidized to sulphur trioxide which raised the " acid " dew-point. If the shaft was of steel and it was cooled below that temperature " acid " dew was formed inside the stack, corrosion took place and large, up to ¼-in. diameter acid smuts were emitted. These had a matrix of ferrous sulphate, carbon and were strongly acid. The emission of these smuts was avoided by keeping the stack temperature above the dew-point by insulation but the material was still discharged to atmosphere.

Dr. Turner said that this brought him to an important point, the question of chimney height. During the dense smog of December 4, 1958, the Central Electricity Generating Board sent up a plane from London Airport. Flying over London above 750 ft of fog, a number of plumes were seen to be penetrating the fog. These were identified in the case of Brunswick Wharf Power Station, Poplar, by the emission of coloured smokes but there was no sign of the plumes from either Battersea or Bankside where the gases were cooled by gas washing. Gases discharged from tall chimneys with sufficient buoyancy to permit the penetration of most inversions permitted the flue gases to disperse in air moving above the fog; this was a most important observation.

A lot of work has been done on the concentration of pollutants at ground level in the vicinity of power station chimneys of different heights; with this knowledge and the knowledge of the quantity and sulphur content of fuel to be burned the probable state of load and height of chimneys it was now possible for engineers to do their sums and ensure that ground concentrations associated with the particular shaft should not exceed a predetermined maximum concentration within certain distances. Efflux velocity was proportional to the load, normally maximum concentrations of SO_2 at ground level occurred at approximately 8–10 chimney heights from its base—but under light loads this distance might be four to six miles and the maximum concentration would of course, be much less.

Dr. Turner hoped that further discussion would do justice to the papers presented.

Dr. J. S. G. Burnett (Medical Officer of Health, Preston County Borough Council) congratulated Dr.

Bronowski on his percipience in the interpretation of present public opinion on the use of smokeless fuels. Those members of the audience who were in regular daily contact with the public on the subject of house heating knew that the housewife accepted clean air as the natural right of the people but she also recognized the drudgery of the old open coal fire and was willing to pay more for the fuel that best suited her convenience. The premium smokeless fuels most certainly met her needs better than ordinary coke.

Unfortunately Dr. Bronowski was away off the beam when he suggested that the demand for these fuels, in absolute terms, was still marginal. The sales of premium smokeless fuels quoted in his paper were not evidence of a rising demand but instead evidence of rising production that persistently lagged far behind the demand.

If Dr. Bronowski was expressing the view of the National Coal Board then it was clear that the Board was well out of touch with popular feeling and did not realize that every ton of premium smokeless fuel made by their competitors in this field was sold as soon as it was produced.

The present output of these fuels fell far short of the demand which itself was still growing vigorously.

What was needed in the short term was an immediate and rapid increase in the production of these fuels to meet the unsatisfied demand.

As to the long term position the National Coal Board could, with advantage, have regard to the increasing interest being shown in whole house heating and to the degree of experimentation that was now going on in many middle class households. These experiments were pointers to the future and it behoved the Board to be in the van of progress rather than to be the bewildered partner of those whose ideas, judged by their propaganda, were still based on a nineteenth century mentality.

G. W. Dhenin (Deputy Chief Public Health Inspector, Bath City Council) referring to the papers given by Dr. Bronowski, Mr. Duguid, and Mr. Jacquest, noted that Dr. Bronowski, and by implication the National Coal Board, thoroughly agreed that raw bituminous coal should be prohibited on all grounds as a fuel for domestic open grates, and that it should be processed by up to date and scientific means into suitable smokeless fuels if our diminishing coal reserves were to be used to the best advantage and to compete with electricity, gas and oil for domestic heating.

In essence, coal was a chemical, packed as tightly with treasure as Aladdin's cave and certainly not to be used as a fuel of so low a thermal efficiency. This was the modern, accredited, scientific view which was gradually being impressed upon the conscience of the public by such societies as ours.

It was sad, therefore, and most frustrating, that the Coal Utilization Council, a Government and National Coal Board sponsored organization, should have advertised nationally the so-called merits of the open coal fire burning bituminous coal.

Mr. Dhenin trusted that the results of the Bronowski research would soon provide, in ever increasing supply, the " convenient ", efficient, solid smokeless fuels at an economic price.

Being a realist, he still believed that a plusage on the cost of bituminous coal to householders and a consequent reduction on the price of solid smokeless fuels would, once the stocks were assured all over the country, bar for ever the use of bituminous coal in open grates.

Despite the views expressed by Mr. A. C. Stern, from the United States, Mr. Dhenin commended Mr. Duguid's plea for strong support from every direction for the Bill to require certification of boiler firemen.

In connection with the paper on diesel fumes from road vehicles, most of the experts present deprecated this low-level toxic pollution. In order to minimize this hazard, and as an interim measure, Mr. Dhenin suggested the use of current practice in other pollution fields—of raising the chimney height; and in the case of trucks and buses, this would at least ensure the discharge of these fumes vertically, in a position where they would have a better chance of dispersal and where offenders would more easily be noticeable.

T. Johnstone (Sanitary Inspector, Motherwell and Wishaw Town Council) said that everyone would be gratified to learn from Dr. J. Bronowski's paper that the National Coal Board had now decided to extend their activities to the manufacturing of premium smokeless fuels.

In some areas especially in Scotland, it had been difficult to obtain sufficient supplies to meet the demand for manufactured fuels such as Coalite, Rexco, Phurnacite, etc. The supply of gas coke, however, had been readily available in areas such as his own, where over 1,200 houses burn only smokeless fuels. It was noted from the press that a private firm hoped to erect a plant at Douglas, Lanarkshire, where smokeless fuels were to be manufactured. It would be of great advantage in helping to meet the rising demands for smokeless fuels if the National Coal Board also made plans to manufacture in Scotland the premium fuels mentioned by Dr. Bronowski in his paper.

P. Draper (Shell Mex and B.P. Ltd.) wished to show no discourtesy to Dr. Delbruyere but he felt that there were either some misprints in his paper or that he had been misinformed on the subject of petroleum products. This in turn had a bearing on the author's proposed solutions to the problems.

Under the heading of Motor Vehicles Dr. Delbruyere referred to the desulphurization of petroleum products which he said contained 3 to 6 per cent sulphur. Mr. Draper said that this was misleading since motor spirits contained less than 0·05 per cent sulphur. Diesel road vehicle fuel contained less than 1 per cent; generally less than 0·5 per cent in this country. In fact no sulphur problem was caused by motor vehicles.

Of the author's five points for reducing the alleged pollution by motor vehicles he pointed out the following facts:—

1. Having made the foregoing points in connection with sulphur Mr. Draper did not think any legislation was necessary and he added that even in the case of heavy boiler fuel oils they contain an average of only 3 per cent sulphur.
2. With regard to tetra-ethyl lead it had been well-known for many years that the concentration of lead exhausted into the atmosphere of cities was quite harmless so that there was no need to convert car engines to compression ignition on that account.
3. Mr. Draper would have liked to hear from the author some details of the carburettor device for reducing fuel consumption and so would every motor car manufacturer! The catalytic after-burner in place of the silencer had been shown to reduce carbon monoxide and unburned hydrocarbons but whether its effect would be lasting or economic was another matter. Such equipment would not be beneficial on a compression ignition engine.

4. As an automotive engineer Mr. Draper stated that it was not normally possible to obtain any extra power by over-fuelling a petrol engine or by tampering with its carburettor.

This was possible however with a diesel engine at the expense of emitting smoke and he fully agreed with the author that it should be an offence to tamper with the settings of the diesel fuel pump for this purpose.

He agreed with the author that the problem of domestic fires was very difficult but he failed to see why Dr. Delbruyere thought there was no gain in using smokeless fuels; which were in fact most fuels except raw bituminous coal. He agreed with some other authors that the reduction of smoke was by far the most important goal of the clean air campaign.

Councillor Mrs. Wightman (Wakefield Rural District Council) declared that Northern England wanted clean air as much as everywhere else, and possibly had more need of it. But the seemingly unsurmountable problem of " concessionary " coal was bringing all the labours of clean air enthusiasts to a halt. Mrs. Wightman remarked that it would be unthinkable, as well as unjust, to deprive the coal miner of a privilege that had been his for generations without giving him something in return. She suggested that the appropriate Ministries and National Coal Board should come to an agreement as quickly as possible so as to enable the miner, living in a smokeless zone, to have " concessionary " premium fuel. And, she added, " concessionary " oil or electricity would not be acceptable in a coal mining area.

Councillor C. A. Watson (Scunthorpe Borough Council) said that there were two points arising from the papers about which he wished to comment. The first was the pollution arising from sulphur fumes. It seemed strange that no comments had been made about the new and successful process devised and, he believed, patented by one of the branches of the United Steel Company for the recovery of sulphur from the carbonization of coal. He pointed out that he had used the word " recovery " rather than " dispersal ". His information had been received from what was regarded as an authoritative source and it had been stated that a fair proportion of capital costs had been recouped by the manufacture of sulphuric acid for use in other by-product processes.

The other concerned the steps being taken by the Coal Board to provide domestic consumers with an adequate supply of solid smokeless fuels.

He asked what, if anything, was being done either by scientists and/or manufacturers to devise and market a domestic grate other than a free standing one which would consume its own smoke, possible by means of a down draught. It seemed incredible that in this day and age it was beyond the capacity of scientists and industrialists to produce such a grate. Indeed, nearly two years ago he had been shown a free standing stove which, by means of a down draught, attained this end. Its drawback was that it did not provide for a back boiler.

If this deficiency could be remedied and the stove given a more conventional or pleasing aspect, the problem of pollution by domestic coal users would be more than half solved.

It ought never to be forgotten that approximately 600,000 men earned their livelihood in the coal-mining industry in hard, dangerous jobs and in many cases socially isolated areas, and that in all thoughts of smoke control these men should not be forgotten or their interests disregarded.

Councillor Miss P. M. Cooper (Metropolitan Borough of Fulham), said Fulham's first Smoke Control Area had been in operation a year and the second one came into force that month (October).

It was difficult to gain the whole-hearted co-operation of the public whilst other forms of pollution continued.

She referred to the huge coke dumps at the North Thames Gas Board's premises, from where, when the wind was in a certain direction, clouds of smoke and dust were blown over the surrounding houses. Then, not far away was the power station with its four stately chimneys, from which at various hours of the day clouds of smoke could be seen, and that was not always white.

In addition when coal was being dropped into the hopper, clouds of coal dust blew over any houses nearby. Surely something could be devised to deal with these problems?

A. D. Cooper (Shell International Petroleum Limited), said that during the discussion it had been stated that desulphurization of fuel oil is currently being carried out in the United States. This was a matter of terminology and he wished to clarify any misunderstanding in the minds of delegates by pointing out that the term " fuel oil " in the United States did not have the same meaning as in North West Europe. Fuel oil in the United States was generally a wholly distillate product whereas fuel oil in North West Europe was a residual containing product. Desulphurization of distillates had been carried out in North West Europe and elsewhere for some considerable time and although ways and means did exist for reducing the sulphur content of residual fuels, the additional processing costs involved, which would to some extent inevitably be passed on to the consumer, would price the product out of court. Considerable research was being carried out in this field but he thought it might almost be said that anyone who could develop an economic process for desulphurizing residual fuel oil deserved to receive the Nobel prize.

A. C. Stern (U.S. Public Health Service, United States of America), reminded the Conference that the day before Professor Kaiser had brought greetings from the Air Pollution Control Association in the United States. As Chairman of its 53rd Annual Meeting to be held May 22–26, 1960, in Cincinnati, Ohio, he invited any who were interested in offering papers to that meeting to do so.

He said that he would also like to bring greetings from the Department of Health, Education and Welfare of the United States, which was the Federal agency charged by Congress with doing work in the field of air pollution in the United States.

Having dispensed with the greetings, he wanted to comment particularly on the paper by the learned gentleman from Belgium, Dr. Robert Delbruyere, " A Commended Solution to the Problem of Air Pollution," particularly the section entitled " Motor Vehicles ". He wished to confine his comments to motor vehicles because it would be inappropriate for him to discuss those aspects of burning coal which did not represent practice on the North American continent.

Specifically there were five points offered by the gentleman from Belgium as solutions to the problem of motor vehicles.

Firstly Dr. Delbruyere noted that ozone was a result of the combustion of petroleum oils. Mr. Stern questioned whether this was a fact. He did not believe that ozone was a significant result of combustion of petroleum products. Also discussed under item 1 was the problem of sulphurous gas from motor vehicles on the North American continent. This was not a problem, because motor vehicle fuels were high quality fuels with very low sulphur content. The sulphur got into the residual fuel oils, which were not burned in motor vehicles, but were burned by power plants and ships.

Dr. Delbruyere also mentioned the question of tetra-ethyl-lead as a problem and indicated that it should be avoided. Actually tetra-ethyl-lead was not going to leave us in the immediate future. It served the economy very well by allowing a larger variety of motor fuels to be offered to the public than would otherwise be possible and by conserving our supplies of petroleum. If anything we would see in the future increased usage of tetra-ethyl-lead, increased quantities of tetra-ethyl-lead in the gasoline and the addition of other additives using both manganese and mercury in addition to lead.

The third point raised had to do with the use of induction devices and after-burners. That represented an area of tremendous research emphasis and interest in the United States. Two or three years ago they did considerable work on induction devices for decreasing hydro-carbons, particularly during the deceleration cycle. There followed a loss in interest in these devices when it was felt the deceleration cycle had been over-emphasized. The emphasis was then placed upon after-burner devices, initially on catalytic devices and more recently on non-catalytic after-burners. There had been a resurgence of interest in induction type devices to be used in conjunction with after-burners. He believed that we would see that come to pass in the near future.

Under item 4 mention was made of sealing carburettors, injectors and pumps. He doubted seriously if that was a workable procedure. He did not think that we would see a time when the owners and operators of vehicles could successfully use the vehicles without access to carburettors, injectors and pumps for adjustment and maintenance purposes.

They had in the United States what were called automobile safety lanes for testing brakes, steering mechanisms and so forth. In the future they expected to add to these safety lanes tests for the effluents from vehicles to insure that they did not unnecessarily add large amounts of pollution to the atmosphere. Trials had been made in the Cincinnati safety lane and it was quite likely that the eventual solution to the problem of photochemical smog would require the mass safety lane testing of motor vehicles, particularly with regard to their exhaust.

W. D. Jarvis (Central Electricity Generating Board), said that with reference to the paper by Dr. Daniel, the information concerning dust deposition and SO_2 concentration at ground level in the published Atmospheric Pollution Bulletin of the Atmospheric Pollution Committee, Department of Scientific and Industrial Research, was being stored on Hollerith cards. From time to time averages were made of the results relating to the insoluble material collected in the standard deposit gauge, and it was shown that during the period 1950–1958 the average concentration fell from 13 to 10 tons per square mile per month. On the other hand, the average SO_2 concentration rose from 2·0 to 2·6 mg SO_3 per 100 sq cm per day during the period 1950–1954, and had remained at that level up to the present time.

The information given in Mr. Lees' paper referred to small industrial plant and he suggested that the conclusions reached by Mr. Lees might not be applied to large concrete chimneys which served modern boiler plant.s For example, the coldest surfaces in boiler plant in power stations might not occur in the chimney and it was possible that acid laden dust was produced initially where the coldest metal temperature occurred, i.e. in the airheater. Moreover, the emissions of acid smuts had been observed only when the boiler plant had been converted from coal to oil-firing. Chimneys were designed to handle flue gases from a number of boilers operating at full load, and a reduction in boiler load, or of the number of steaming boilers would reduce the efflux velocity of the flue gases from the chimney and their dispersion into the atmosphere. Tests carried out at a power station showed that when a 350 ft chimney was loaded to design capacity; the maximum dust concentration occurred at distances of 8 to 10 chimney heights, but at weekends and at other periods of low station loading the area of maximum dust concentration moved inwards to a distance of from 4 to 6 chimney heights.

Professor E. R. Kaiser (New York University, United States of America), said that he believed that the Chairman had called on him on this occasion not to take the heat off the Alkali Inspectorate, but rather from the fact that no one from the United States had contributed a paper at that session and the Chairman did not want the United States delegates to get by with that. However, with regard to a number of the papers, he was trying to make his comments brief. One of the papers has mentioned the increase of sulphur content in coal in Britain, and had mentioned that a somewhat similar trend was taking place in the United States. However, Professor Kaiser assured the Conference that the United States started at 2 per cent sulphur and there was in the United States any amount of coal at 3 or 4 per cent sulphur. So Britain's problem was not quite as bad as America's. However, the warning was well taken; Britain would be having an increase in sulphur content and particularly as she got on to burning oil. To take the sulphur out of the coal, at least to a greater extent than had been done (Dr. Lessing had an excellent discussion on it), some of their thinking in the States was that if coal could be pulverized as was being done in large plants, and that the cleaning then take place because the sulphur had been liberated—the smaller particles that had been shot through the coal had been liberated—and by processes still to be developed much of that sulphur might be taken out and used for some other purposes, at least not burned in plant and put into the atmosphere. That was something in contradiction to the idea that the large utility plants should use the lower grade middlings; it was going to be quite a while until they worked that one out.

There were some claims in the United States that sulphur could be removed from fuel oil economically, but that had not been proved sufficiently. There was quite a bit of resistance to trying to do anything with removing sulphur from the oil. There was also much resistance, of course, to removing sulphur from the flue gases. The SO_3 in production, while it was of the order of 1 or 2 per cent had been increasing due to the fact that they were making higher temperature steam, their super heaters were running at higher temperature, and the iron oxide on the surface of the super heater tubes was a good catalyst. That had been well investigated in Britain and the United States looked to British reports on that mechanism.

Professor Kaiser said that their experience in the education of stokers had been really so unsuccessful that they tried to build the brains into the machinery, into the firing mechanism, and then have gauges and instruments, he supposed some day even computers, to tell the operators how to make the adjustments. He was afraid that that was going to have to be the practical answer for quite a while in that direction. Of course that meant that certain engineers were going to have to know more about the subject than ever before, and the larger plants could employ such people.

Professor Kaiser continued by saying that Dr. Kettner's paper was very interesting. The use of a water spray in connection with a cyclone was undoubtedly very effective for certain kinds of grit. However, much more intimate contact of water and flue gases and their contaminants would be necessary and delegates had seen some examples of spraying gas washers, sçrubbers, along the walls of the Conference Hall and they had scrubbers in the United States, made and sold in Britain also, that did quite a good job, but to get that intimate contact required a power from the fan, and usually a number of stages for re-mixing the re-entrainment and that was quite effective. However, the gases were cooled and that introduced some of the problems delegates had already heard mentioned. In America they had had quite a bit of success in investigating the design contours of power plants, and the heights of stacks, as well as the question of stack velocity by making models of the plants, trying out various configurations and so on in what they called a low velocity wind tunnel.

Professor Kaiser concluded by saying that the New York University had done good work on that for the utility companies and there were quite a few reports to which he would like to call the attention of the Conference.

P. Humbel (B.P. Belgium Societé Anonyme, Belgium), agreed with the main conclusion of Mr. Riello's paper: correlation existed between soot formation, design adjustment and working conditions of the heating plants.

But Mr. Humbel expressed the opinion that the difference of the weight of the soot (Table 1 to 4) could be, in some cases, of the same accuracy as the test procedure, or could have been influenced by other factors than those reported.

He then asked if Mr. Riello had the opportunity to carry out further investigations on individualizing the influence of each factor, the others being kept constant.

In Mr. Humbel's opinion, the main factors to be individualized are: atomisation, fuel rate, CO_2, kind of fuel, draught evenness, combustion chamber (shape, size, temperature and thermal inertia of the walls), acid dew point of the gases, temperature of metallic skin (gas side) of the heat exchanger, working conditions (start and stop or continuous), etc.

Author's Reply

B. Lees said that smuts had been observed with oil firing and they had overcome the problem. They were not, however, confined to oil firing. The total emission of sulphur dioxide after conversion to oil firing was often lower than with solid fuel firing, because the calorific value of fuel oil was generally at least one and a half times that of solid fuels and also fuel oil was frequently burnt with higher efficiency. Conversion of 5 per cent of the SO_2 present in flue gases to SO_3 was exceptional. Their determinations had shown that the conversion was generally below 2 per cent.

The total quantity of dust and acid which fell in a neighbourhood as smuts was generally very small, although the smuts might cause a local nuisance. When smut emission was eliminated by maintaining ducting and chimneys above the acid dewpoint the dust was discharged as separate particles, instead of agglomerates, and the acid as gaseous sulphur compounds to the atmosphere. The quantity was negligible. As stated in the paper, stack solids in the flue gases from oil fired boilers could be below 10 grains per 100 cu ft.

Replying to the comments of Mr. Jarvis, it was agreed that the coldest surface in boiler plant might occur in the airheater and not in the chimney. It appeared, however, that this did not contribute to smut emission because:

(a) Many airheaters had been examined where corrosion was occurring, but smut emission had not been noted near to the power station.
(b) If smuts were carried forward from the airheater they might either be broken down in passing through the i.d. fan or settle in the duct between the i.d. fan and the chimney.
(c) If smuts could be carried forward from the boiler, one would expect severe smut emission to occur during soot blowing. This had not been observed.

It was suggested that if Mr. Jarvis were to arrange to analyse the smuts which occurred near to a power station, this might act as a guide to the source of the smuts. If they contained less than 5 per cent iron, then they had probably formed in the concrete chimney. If they contained more than 5 per cent iron, they might have formed in the steel duct close to the chimney.

Dr. J. Bronowski thanked the Conference for the interest shown in his paper and drew attention to those points in it which answered the questions raised in the discussion. He underlined particularly those passages towards the end of his paper in which the National Coal Board formally announced its policy and plans for the development of new smokeless fuels.

Dr. R. Lessing said the sulphur problem had loomed large throughout the discussion. He would like to make only one point in regard to Professor Kaiser's remarks about coal middlings. In order to avoid confusion he must emphasize that the problems of utilization of clean coal and of washery refuse and their influence on Air Pollution were quite distinct though inter-related.

In removing impurities, both ash and sulphur bearing minerals, from raw coal the question of pollution of the air from the refuse heaps arises.

Dr. Lessing proposed that the refuse should not be allowed to be spontaneously ignited but that it should be burned under controlled conditions. If this was done it would be advisable to add the most impure portion of the middlings to it and thus make the clean coal cleaner and raise the calorific value of the refuse.

Not only would the heat value of the refuse be realized but an incombustible residue would be obtained, not liable to spontaneous combustion and emission of sulphur fumes, a material which, in Dr. Lessing's view, should be taken underground by wet or dry stowage to counteract another great evil, namely subsidence in the mining areas

Session IV—Observation, etc. of Air Pollution

Review by Dr. E. T. Wilkins, Rapporteur

Dr. Wilkins said:

The majority of papers to be discussed at this Session deal with measurements of common pollutants in the free atmosphere. These papers come from many countries and, together with those dealt with in other Sessions, provide the most comprehensive appraisal of pollution in different parts of the world that we have seen.

The measurements are mostly of deposited matter (" dust-fall "), suspended matter (" smoke ") and sulphur dioxide, and they are made mainly for local authorities for the purposes of control. The methods have been developed to meet local requirements and, since these are mostly of an empirical character, correlation between the results they yield is often poor. This is confirmed by Schwarz and his associates (Paper No. 57) who describe a pollution survey in Essen in which three types of deposit gauge were used. Paper No. 47 describes the organization of air pollution studies in a number of Japanese towns and gives some of the results. There are three papers from Italy; No. 43 by Giovanardi and his associates on pollution in Milan, No. 54 by Paccagnella on Padua and No. 55 by Petrilli on Genoa. The measurements were made by the methods used in Britain and a comparison of the results with those published by the Department of Scientific and Industrial Research shows that the degree of pollution at the Italian sites was similar to that in British towns; the most heavily polluted being similar to those in, say, the most heavily polluted part of London.

The British methods of measurement are also used in S. Africa, and in Paper No. 45 Halliday gives the results of measurements in Pretoria, Johannesburg, East London and Durban. Here again we find degrees of pollution comparable with those in average medium-sized British towns. These conclusions from the Italian and S. African results seem to me to have important implications worthy of discussion by the Conference.

Investigations such as these show the value of these simple survey techniques for indicating the growth and extent of the pollution problem and where there is a need for administrative action. But are the administrative bodies sufficiently alive to the significance of these scientific studies? According to Halliday and Paccagnella, some are not; this, however, is a problem belonging to Session II.

There is a wealth of detailed information in Paper No. 41 by Besson and Pelletier on air pollution in Paris. Measurements of smoke and sulphur dioxide are made by methods analogous with those used in Britain and these show that on the average the air of central London contains about 70 per cent more smoke but only 20 per cent more sulphur dioxide than that of central Paris. The highest concentrations of sulphur dioxide have been found in the neighbourhood of well-to-do blocks of flats and this is attributed to the considerable emissions of new smokeless heating installations. However, it is my impression that Paris is not the only place where " smokeless " equipment has sometimes been installed with inadequate provision for the dissipation of the sometimes increased amounts of invisible pollutants.

The investigations of Hettche (No. 46) on smoke-particle counts are interesting, particularly because little published information is available on the smoke content of the air of German towns. Since in many countries smoke is considered a particularly noxious pollutant which is regularly monitored, it would be interesting to have the comments of the German delegation on this apparent difference in outlook.

Paper No. 50 by Kirste refers to an investigation to discover the source of pollution which was causing damage to vegetation. The measurements reported are of deposited matter although, for such effects, gaseous pollutants might normally be more suspect.

Another paper dealing with the study of the distribution of pollution around a particular source is that of Cummings and Redfearn (No. 42) which refers to short-period measurements of sulphur dioxide around an electricity generating station. The instruments used in this work consisted of an automatic recorder and a simpler transportable instrument. The latter instrument proved useful for locating the zone of maximum pollution in the lee of a chimney and for measuring the concentration there. In this way it was found that the chimney gases seldom raised the ground-level concentration of sulphur dioxide by more than 30 p.p.h.m. Whether this is much or little is a matter of opinion, but, obviously the magnitude of the background pollution is an important factor.

The question of additive emissions is discussed by Berge (No. 40) who points out that a number of emissions each by itself unobjectionable, may have a combined effect (referred to as the " immission ") which is thoroughly objectionable. Thus, it is suggested, the control of pollution should be on the basis of immission rather than emission. Such a logical approach to this important and difficult problem involves obvious administrative difficulties but we are told that the U.S.S.R. has a law in which immissions are used as a basis of pollution control.

I have already referred to the fact that measurements of pollution made by different methods are not generally comparable. This lack of uniformity may be of no great importance when the use of the results is confined to local control. In recent years, however, measurements by such methods have been used with increasing effectiveness in epidemiological studies of the effects of air pollutants on public health. Paper No. 61 by the Medical Research Council's team at Sheffield is a particularly elegant example of this technique. In the paper by Buxell (No. 59) we are reminded that a report by the World Health Organization suggests international co-operation in such epidemiological studies, and that for this to be possible some degree of international standardization of methods of measurement would be necessary. The papers by Katz (No. 49) and Kirste (No. 50) also stress the importance of such standardization. As some delegates will know a start has been made on this problem by a Working Group set up under the auspices of the Organization for European Economic Co-operation.

The papers so far discussed have been concerned with relatively simple methods of measurement but there are many other techniques required for research and control purposes. One which is being studied experimentally for the measurement of air-borne particulate matter in chimney effluents by an electrostatic method is referred to by Grindell (No. 44). Another is that developed by Spurny and his associates (No. 58) for the collection and examination of aerosol particles in the size range of 0·05 to 50 microns. The excellent electron-micrographs which are reproduced show the complexity of the groupings which comprise the smoke particles we inhale and indicates that we still have a great deal to learn about the physico-chemical properties of these particles.

The paper by Lucas (No. 52) is a condensation of an advanced mathematical exercise designed to calculate the domestic contribution of smoke and sulphur dioxide to town air under British conditions. In the calculation it has been necessary to eliminate a number of variables and so an idealized result has been deduced which shows the average concentrations of pollution rising rapidly with increasing size of towns in the case of small towns and increasing relatively slowly with larger towns. Comparing these calculated results with the latest information available on the measured concentration in many parts of Britain one finds that the scatter of the measured points almost if not completely obscures the effect of the size of the town. However it is a considerable achievement to calculate even approximately the ground-level concentrations of pollution. If this method can be suitably adapted it may simplify considerably the practical work now required for air pollution surveys.

Administrative and practical aspects of Durban's Cleaner Air Campaign are described by Johnson (No. 48). Some of these are along familiar lines, e.g. training courses for stokers, smokeless zones, smoke control by-laws and prior approval for new plant. To encourage factory owners to take more interest in the smoke emissions of their chimneys an order of merit scheme has been introduced. The problem of smoky diesel vehicles is being tackled by withdrawing the licences of offending vehicles. I believe a similar method of dealing with this latter nuisance and possible hazard is also being applied in a few other places but it has never been clear to me why such a simple remedy is not more generally adopted.

I think you will agree that this group of papers adds greatly to our knowledge of the science and technology of the measurements of air pollution.

Discussion

Dr. Albert Parker (Royal Society of Health), in opening the discussion said that the methods of measurement required could be divided into two main groups (a) those to be used for continuous routine surveys of the levels of pollution and (b) those to be used for special investigations and research. For routine surveys the methods and instruments must be simple and inexpensive. Such surveys were begun in Great Britain about 50 years ago and simple instruments had been developed for measuring deposited solid matter, suspended particulate matter of " smoke ", and oxides of sulphur. The survey had grown slowly at first and then rapidly during the last 10 to 15 years. In 1945 the total number of instruments in regular use by local authorities and other co-operating bodies was only about 200; now it was over 3,000 at sites over most parts of the country. Several countries in Europe had adopted the British instruments, but in some other countries other designs of instruments were in operation. The several types of deposit gauge, for example, gave results that could not easily be compared. International standardization was desirable. There was already an active Committee of the Organization for European Economic Co-operation endeavouring to achieve such standardization. The World Health Organization could also assist so that the data obtained in the various countries would be comparable.

With the advent of nuclear power stations and the increasing use of radioisotopes, surveys were required for measuring the intensity of ionizing radiation. In general, regular routine surveys of radiation over a country might well be made by the larger local authorities at widely separated positions.

Instruments for research, which would often be expensive, could not be standardized without detriment to progress. New instruments and methods had to be developed in investigating new and special problems. For example, new industries and changes in industrial operations often gave rise to new pollutants; further information was needed on the effects of chimney height and micro-meteorological conditions on the dispersion of pollutants, particularly at times of temperature inversion in the atmosphere. More information was required on the maximum concentration of pollutants that could be tolerated without detriment to health, agriculture and materials. The " smog " of Los Angeles, which occurred in the warmer weather, was quite different in the main from the winter " smog " of London, and required different methods of study. There were even special problems of pollution in some so-called under-developed countries. In villages in India, for example, there was very unpleasant pollution at low level when the villagers were doing their cooking using dried dung as fuel. There was pollution problems also from cooking food in some African communities. All these special problems required special methods of measurement and investigation aimed at preventing or mitigating the pollution.

B. Lees (British Petroleum Co.) drew attention to the analyses of the samples reported in Paper 46 by Professor Hettche. The analyses of the " oil soot " showed that it was typical of " acidic smuts " described in Mr. Lees' paper. He considered that this must have formed originally on a " cold area " in the boiler ducting or stack and then been re-entrained in the flue gas stream. Experiments reported in Paper 38 showed that there was no measureable increase in free acidity of soot when the SO_2 content of the flue gases were increased in a *heated* flue. Mr. Lees said he would be pleased to co-operate with Professor Hettche in Germany to overcome this problem. The methods described in Paper 34 had now been successfully applied in over 50 installations in the United Kingdom, Australia and New Zealand.

C. A. Stansbury (Chief Public Health Inspector, Borough of Walsall), said that a tribute must be paid to the work of the Department of Scientific and Industrial Research and the Atmospheric Pollution Research Station at Greenwich, for the work they had done on the observation, investigation and measurement of air pollution, and it was largely due to their work that local authorities in the United Kingdom had responded so well and were now making a record number of observations and measurements. It was most appropriate that in that afternoon's session, Dr. E. T. Wilkins was acting as Rapporteur and that the discussion should have been opened by Dr. Albert Parker.

He continued that he was not technically equipped to deal with the scientific aspect of investigation and measurement, but was naturally concerned with the use that was made of the results of the investigation of pollution and the interpretation of the results. Local authorities were naturally concerned to bring into operation smoke control areas and other remedial works under the Clean Air Act, but they found their work was made much easier if there was an informed public opinion prodding local authorities into action.

He found that many statistical records in connection with atmospheric pollution were not in a form that tended to gain the confidence of the public. There was a distrust of statistics and it was most helpful if they could see for themselves the effects of atmospheric pollution. While it might still be necessary to build up local, regional and national statistics of deposit gauge and lead peroxide readings, he had found that the daily volumetric smoke recordings which indicated on a filter paper the amount of smoke polluting the atmosphere, when put on show and correlated with reports of weather conditions, were most helpful in gaining the attention of the public. He had also been most impressed by the accuracy of reflectometer readings.

By all means let them have all the observations, investigations and measurements they could get, but let them use the results in the best way possible so as to ensure that the overall effect was a move forward in their efforts to get a clean atmosphere.

D. S. Wilson (Central Electricity Generating Board), said that the Central Electricity Generating Board made routine monthly measurements in the areas around over 50 power stations and for this purpose used standard deposit gauges and lead peroxide candles. The results obtained appeared in the Department of Scientific and Industrial Research Monthly Bulletin which was circulated to all organizations making measurements. However, the C.E.G.B. felt that merely making monthly measurements did not constitute a full survey and additional techniques such as directional types of deposit gauges, microscope examination of collected solid material, and continuous recording of the SO_2 concentrations in the air were therefore also used.

The origins of the grit particles which were found in industrial areas could often be determined by microscope examination of the dusts, since many dusts had characteristic appearances related to the industrial process from which they were emitted. The microscope examination technique was originally developed by Dr. Crossley at the late Fuel Research Station and had often proved invaluable in tracing the real sources of deposited dust and grit in industrial areas.

It was recognized some years ago by the C.E.G.B. that measurements of the sulphur gases made with lead peroxide candles were not completely satisfactory, since they gave only an indication of the average sulphur dioxide content of the atmosphere and no indication of whether high concentrations of sulphur gases had existed for short periods during the time of exposure of the candle. For this reason, two instruments were developed to measure the concentrations of SO_2 in the air and their use was described in Paper 42 by Cummings and Redfearn. Some measurements obtained with these instruments had already been reported elsewhere.*

Mr. Lucas, in Paper 52, showed how the concentration of sulphur dioxide in the air in and near towns could be calculated.

The C.E.G.B. were investigating the practical applicability of the various formulae which existed and which related ground level concentrations of pollution to chimney height, velocity and heat content of gases, and meteorological and other variables.

It was understood that the Central Government was inquiring into the complicated subject of the chimney heights which were necessary for the adequate dispersion of effluents.

It therefore appeared that it was already known, or it could reasonably be expected, that in the not too distant future it would be known:

(a) How to accurately measure SO_2 concentrations of short duration which occurred in the air.
(b) How to estimate the SO_2 concentrations which would arise from cities.
(c) How chimney height and other factors were related to concentrations of SO_2 which occurred in the locality.

The Medical Research Council teams were investigating the difficult subject of the medical effects of pollution and each of their reports merited careful attention. The evidence so far available seemed to indicate that sulphur gases in some form were one of the pollutants which affect health, especially during foggy weather, but the mechanism of the attack was as yet unknown.

In an industrial country whose economy was largely dependent on the burning of fuels, the complete elimination of pollution was not yet possible. It should be possible by good planning to achieve much lower levels of pollution than now often existed in industrial areas, but to achieve unnecessarily low levels of pollution could be extremely difficult and costly. It seemed that a position would be reached in the forseeable future when, adequate methods for the measurement and control of pollution to permissible limits in industrial atmospheres would be available. These limits however must be defined by the medical profession.

Councillor W. A. N. Jones (City of Birmingham), said that the two excellent papers from South Africa showed how comparable even domestic chimney smoke in such towns as Pretoria and Johannesburg, was with like pollution in such towns as Ilford, Leicester and Portsmouth. They had, however, adopted much of the experience gained by their British counterparts. So much indeed, to their credit, might we in Great Britain learn from them. Their encouraging methods in fuel efficiency were worthy of note, by which industrialists took part in a scheme of points awards for the least emissions over given periods and Certificates of Merit were awarded. These records were used by some firms as a basis for awarding bonuses to the successful firm's stokers.

We should also adopt their method of dealing with air pollution by road motor vehicles, by which provision existed for taking vehicles off the road until excessive exhaust smoke was rectified.

W. Lawson (National Coal Board) asked how well established were statements made in Paper 44, by D. H. Grindell, that " detrimental effects upon health are governed more by size distribution, surface area and fundamental chemical and physical properties of the impurities " (of air-borne particles); and that " Smoke and dust particles within the range 0·1–1·0 microns diameter are largely responsible for the formation of industrial fogs, as well as being pathologically the most dangerous . . . ". Were these statements accepted by the Medical Research Council, for example? If so, the facts should be more widely known, so that suitable instruments and techniques could be generally adopted, in preference to optical and gravimetric instruments for measuring such pollution.

P. Draper (Shell Mex and B.P. Ltd.) said that he thought that Dr. Besson and M. Pelletier had described the results of much good work in an attempt to correlate measurements of flue gas constituents in the atmospheres of several large cities. Their problems were confined to the nature, origin and distribution of pollutants most dangerous to health.

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* Cummings, W. G. and Redfearn, M. W., Concentration of SO_2 in the Air near Power Stations. *J. Inst. Fuel*, Aug. 1959, Vol. 32, p. 358.

Carbon dioxide was obviously the pollutant greatest in quantity and their two comments were of interest and might, therefore, be emphasized. The first point was that no other acid compounds in the atmosphere were present in greater quantity than one three-hundredth of that of carbon dioxide and secondly that in Paris the population of 5·5 million exhales 2·2 million tons of carbon dioxide per annum; whereas all forms of combustion in the area exhaust only ten times as much during the year or four times as much in the summer when breathing continues but combustion is reduced.

Under the heading of Sulphur Dioxide the authors had declared rightly that this gas lends itself very well to routine determination, in other words, it might be regarded as a relatively easily measured tracer of total pollution.

The authors followed this with the bald statement that sulphur dioxide appeared to be the most dangerous pollutant. Mr. Draper admitted that he agreed more with Professor Hettche in Paper 46 in which he made the point that sulphur dioxide alone was not as harmful as it is combined with particulate matter such as smoke and dust in the particle size range of ·25–10 microns which may pass the nasal filter and reach the alveoli.

Mr. Draper felt that he must take exception to the wording of the authors' comments on oil fired central heating in Paris. They stated that this form of heating emitted large amounts of sulphur dioxide: what they really meant was that it emitted negligible quantities of smoke. In fact, such plant would emit sulphur dioxide in quantity from rather less than one-fifth of that from the equivalent solid fuel domestic equipment. The reason for a higher recorded sulphur dioxide content was undoubtedly due to the more adequate heat being supplied to more houses.

T. Henry Turner (Individual Member), commenting from his own experience about points mentioned in the paper by Professor H. O. Hettche, said that words used by doctors and other scientists often needed explanation before they became comprehensible to other men and women.

The " synergic effect " referred to by Professor Hettche was a term better known in France and Germany than in this country. This Greek word meaning " to work with " had a Lutheran theological meaning in the Middle Ages, that the combined action of faith and works were needed for salvation, a fruitful idea.

Professor Hettche used the word " synergy " for the combined action of sulphur oxides, grit, and the human lung in a smog.

When visiting metal smelting plants in Canada, where much dry sulphur dioxide was emitted, Mr. Turner's eyes had been temporarily blinded by nature's defence mechanism of copious tears which washed away the irritant.

In a smog we might swallow, blow out, or spit out atmospherically polluted saliva or mucous, but if such elimination of the pollution should prove to be an inadequate defence it would perhaps be helpful to remember the following.

Weak muriatic acid only 5 per cent strong was used to clean the exterior of railway carriages and in tests in the laboratory it never attacked the varnish. However in the open the sun evaporated the water, the acid concentrated, and held to the surface by the dried mucous it ate through the highly resistant varnish. So it seems that working together " synergetically " in a smog sulphur oxides and moisture and grit particles could form by catalytic action and evaporation of the water, a concentration of relatively strong sulphuric acid which may be held on to the lung surface by particles of grit or dust and so do more damage than SO_2, SO_3, or grit alone.

The corrosion of metals was mentioned on the same page and it was surprising that no paper had been presented to the conference stressing the effect of atmospheric pollution in increasing atmospheric corrosion.

In the work of the Atmospheric Corrosion Committee pollution figures had been correlated with corrosion losses. The British Iron and Steel Research Association had records of tests on their specimens, which had been sent to many parts of the world and exposed in industrial, urban, rural, and marine atmospheres. He had been intimately connected with this work for over 20 years and he could state definitely that increase in the sulphur and grit pollution of the atmosphere caused a proportional increase in the loss by corrosion of iron or zinc.

" Standardization " of measurements had been a great help in Great Britain. Dr. Parker had mentioned the tremendous increase during the last ten years or so from 200 to over 3,000 testing instruments. In 1945 someone went to the Director of the British Standards Institution and said that to increase the usage of instruments for the measurement of atmospheric pollution, instruments were required with the prestige of being the British Standard. Consequently B.S. 1747: 1951 " Deposit Gauges for Atmospheric Pollution " appeared and was in use before the London smog. Thus measurement of atmospheric pollution ceased to be the peculiarity of cranks and became more widely recognized as officially respectable.

Mr. Turner therefore strongly supported the proposals for international co-operation in the production and standardization of the most suitable instruments, and he wished the overseas delegates to note the large number of instruments, now used by many hundreds of authorities in Great Britain, in accordance with standard specifications.

D. L. Newton (Monsanto Chemicals Limited), referring to a paper by D. H. Lucas on the " Estimation of Sulphur Dioxide from Domestic Sources " suggested that, when taking air pollution measurements, particularly in rural areas, wind direction was a very important factor. He suggested that, only by taking wind direction into account throughout the duration of the estimation could a reliable assessment of local pollution or the location of a polluting source be made.

He concluded by asking the author why a wind direction recorder was not part of the standard air pollution equipment.

Councillor F. E. Cheek (Durban City Council, South Africa) said that after hearing the wonderful reception of Mr. Johnson's paper he was really proud to be the Chairman of Durban's Cleaner Air Consultative Committee and he very much regretted that Mr. Johnson had not been able to attend.

He was disappointed to find that Dr. E. C. Halliday, in his paper, had given very little credit to Durban's Cleaner Air Campaign. Durban was extremely furtunate, some three and a half years ago, in selecting Mr. Johnson from many applicants in Britain, as its Air Pollution Control Engineer. With Mr. Johnson and his six inspectors Durban had given a lead not only to the Union of South Africa but to the whole of Africa. Durban had had visits from health officials in the various towns and cities to gain all the information they could before embarking on a similar scheme.

Councillor Cheek said that in the previous session of the conference reference had been made to sealing fuel pumps. Some 12 months previously Durban had considered regulations governing the sealing of fuel pumps. To their amazement they were informed that "sealing of fuel pumps would not prevent the parts wearing". Buses were often to be seen in some Durban streets three abreast, racing for position and of course there were no London police to control them. This necessitated early morning adjustments.

Durban's method of dealing with this problem was very simple. When a bus was seen emitting black smoke from the exhaust they took the bus off the road and withdrew its Roadworthy Certificate until the necessary adjustments had been made. They were engaging additional staff, including traffic police, and when the scheme was in full operation the Durban garages would be working overtime, as no one could afford to have his buses off the road.

The Durban authorities were running classes for both European and Non-European stokers, and on the three occasions Councillor Cheek has presented the certificates he had stated that the day was not far distant when all stokers would be compelled to hold these certificates. In South Africa an electrician must have a certificate so that he would not kill people, so why not a stoker who killed people with smoke? He looked forward to the day when such legislation would be introduced.

Some three months previously they had introduced a Smokeless Zone, and when that was well in hand it was their intention to create further such zones.

In conclusion Councillor Cheek said that he would like to congratulate the National Society for Clean Air on its wonderful work and the success of the conference.

L. Truffert (Conseil Supérieur d'Hygiène Publique de France) in a written contribution to supplement the paper by Dr. Besson and M. Pelletier, said that it was in 1935 that he had, for the first time, to study a problem concerning air pollution. He had accompanied Mr. E. Kohn-Abrest who had been charged together with Mm. J. Renault and R. Fabre by the "Conseil Supérieur d'Hygiène Publique de France" to make a study of the air pollution of the region of the Havre (Seine-Maritime) by a petrol refinery.

The products treated were very rich in sulphur and the gas ejected contained sulphuretted hydrogen, mercaptans, thioethers, etc., substances which gave a bad smell to the air, even at an extremely low concentration. That inconvenience was obviated by collecting as much as possible the bad smelling gases and burning them before ejecting them into the air.

In 1936 he was charged with another problem. This time it concerned the region of Salsigné, in the Département de l'Aude, where a factory working on beds of mispickel containing gold and silver was situated. From 1925 to 1936 that factory had discharged with its smoke about 7,500 Kg of arsenoius oxide per day, this caused arseniasis and 230 cases were diagnosed by doctors, among the surrounding population.

The smoke was ejected at first by a 35 metres high chimney and when in 1931 a new chimney 115 metres high was built it had no other effect than to disperse farther away the arsenical dust (result similar to that obtained at Anaconda). The intoxications could originate for a great part, in the use of wine coming from vineyards submitted to arsenical smoke. He proceeded to the study of 79 samples of must from a vintage of 1936, and in which he had been able to reveal the presence of arsenic in proportions variable with the exposure of the vineyards and attaining up to 27 mg of As per litre.

At that time, the equipping of Cottrell electrostatic appliance for freeing air from dust was pushed on, and the quantity of arsenic sent daily into the air fell to 400 Kg, then to 275 Kg and finally to less than 20 Kg. As a result of his study of musts from 1938 vintages of that region, he only found proportions of arsenic less than 1 mg per litre, save in one exceptional case (2 mg per litre). The arsenical noxiousness had practically disappeared, but, of course, there were still relatively high contents of arsenic in the plants of this region and these seemed to be in relation with the nature of the soil.

However, the factory kept on being a source of air pollution, for it cast out with its smoke amounts of sulphur dioxide which from 80 to 90 tons a day in 1935 went progressively down to about 15 tons in 1946.

At that period he had been appointed with Mr. Darzens reporter of the questions concerning air pollution to the "Conseil Supérieur d'Hygiène Publique de France". After the death of his lamented colleague, he had pursued alone that study and produced several reports on the subject.

From 1946 to 1949 complaints were expressed in diverse parts of France by reason of the air pollution caused by certain factories.

In some cases the complaints had concerned factories producing sulphuric acid, notably in Piere-Bénite (Rhône) and in Donville-les-Bains, near Granville (Manche).

In the last place various improvements brought in 1947 and 1948 had proved to be insufficient and the "Conseil Supérieur d'Hygiène Publique de France" charged Mr. Kohn-Abrest and himself to accomplish an investigation locally to try to find adequate means to palliate the pollution.

Having accomplished their mission in October 1949, they had the satisfaction to note that the measures they had recommended had proved to be adequate, and all complaints ceased. However the anxiety was so great in the region that he had to inspect a factory in the neighbourhood (sulphuric acid and superphosphates) in Dol de Bretagne (Ille et Vilaine) to ascertain, in May 1950, that it did not constitute a danger for the population.

In some other cases, they had to do with factories producing synthetic herbicide (2–4 Dichlorophenoxyacetate) and the chlorophenolic smell they gave out, inconvenienced the neighbourhood, notably in Saint-Aubin-les-Elbeuf (Seine-Maritime) in 1948, and in Arpajon (Seine et Oise) in 1949. There again the recommended measures were effective.

In Tours (Indre et Loire) where he was called with Mr. Walter, the inhabitants complained about the emanations coming from the gas-works and from a tar-treating plant. The problem proved to be a difficult one, for the town of Tours is situated leeward of the industrial zone where many factories contributed to the air pollution.

In certain valleys of the French Alps, another problem claimed their attention from the presence of factories treating aluminium. These were the origin of serious pollution by fluorides which caused damage to the plants and livestock (particularly in 1942) but as far as he knew, there were no cases of human poisoning.

In order to make better known the importance of air pollution he gave an account of his researches on that question, first on January 9, 1951, in a lecture at the "Société des Hygiénistes et Techniciens Municipaux" then on November 27, 1951, at the 24th

" Congrès International de Chimie Industrielle ". After this lecture, the " Congrèe International " expressed the wish that " national organizations be created in order to study air pollution problems and help manufacturers to improve their production whilst complying with the necessities of hygiene ".

That resolution having been sent to the public authorities, he was charged, in January 1954, to submit a new report to the " Conseil Supérieur d'Hygiène Publique de France ". Shortly after another resolution expressed by the " Musée Social " after a lecture by Mr. Florentin on this subject, having been sent to the Ministère de la Santé, it was decided to study it with the former.

After hearing the report he gave on that subject on April 12, 1954, the " Conseil Supérieur d'Hygiène Publique de France " asked that while the constitution of the national organization remained essential, an interdepartmental committee be actually formed and charged with the study of these problems.

The first meeting of the interdepartmental committee took place on November 9, 1954, with Mr. V. Raymond as Chairman. Since then it had met about a dozen times, studying the air pollution inherent in the presence of new steam generating stations, the development of motor traffic, etc.

Sometimes, air pollution problems cropped up in the Union Française. That was why he went to Dakar in April 1959, to study with Mm. Courbin and Gallet the pollution caused by the steam generating station of A.O.F. which burned fuel oil of a high sulphur content.

The Titrilog apparatus had enabled him to record in the houses amounts of sulphur dioxide attaining, during several hours, an average of 2 p.p.m. (2 ml/m^3) and exceeding in some cases 7 p.p.m.

Important measures would be brought into play to make this pollution cease, for the trade-winds, blowing for long periods of time in the same direction, made it all the more serious.

Finally, he pointed out that societies had been constituted in France to combat air pollution: firstly, the Association Pour l'Air Pur (Journal officiel of October 25, 1956), then the Association pour la Prèvention de la Pollution Atmosphérique (Journal officiel of August 10, 1958).

The action of these societies was likely to help the work of the interdepartmental committee.

Authors' Reply

Dr. H. Kirste said that in his paper he had emphasized the necessity of standardizing the methods of measuring air pollution. He knew of course that it would be very difficult to realize this purpose because of technical questions. At first the problem of finding out the best method had to be settled. Another point of view was that till now the different nations and various institutes had developed methods of their own and were using quite a lot of expensive apparatus. Therefore it was not easy to change them.

He did not agree, however, with objections raised in the discussion that standardization would threaten the freedom of research. This opinion seemed to be misleading. In his work, of course, every researcher could use whatever methods he liked even if they were not standardized. But to examine his results and to compare them with those of others every researcher depended on standard methods. There was no denying the fact that practical work required conventional methods so that the results of the praxis could be recognized generally and internationally.

D. H. Grindell said that the most serious effects upon health created by atmospheric pollution were due to its inhalation and he believed it was well established that the filtration efficiency of the respiratory system was dependant upon the size of the airborne particles. Those greater than about 12 microns were trapped in the nose, whereas those of about 1 micron and under were able to reach the lungs. The degree of irritation caused clearly depended upon the chemical composition of the deposited matter—for example, whether or not it had a sulphur content. Surface area was important when the particles tended to be dissolved in the lung fluids or, perhaps, whilst still airborne.

There had been much recent work done in this field, especially in connection with the pneumoconioses, and a review had been given by Green and Lane in their book " Particulate Clouds, Dusts, Smokes and Mists " (SPON, London, 1957).

He thought, however, that intensive research would first be necessary before suitably cheap and simple equipment was devised and generally adopted to replace existing methods, but the technique described in Paper 44 appeared to be a step in the right direction.

Dr. Besson and J. Pelletier replying to Mr. P. Draper, said that it was well known that sulphur dioxide at concentrations found in town atmospheres might be considered as having little or no toxicity. Nevertheless, its solution or adsorption on liquid or solid particles present in the atmosphere facilitated, by catalytic surface action, its oxidation to sulphur trioxide and sulphuric acid.

It was these resultant oxides and acids, derived from sulphur dioxide, that in association with particles were probably the origin of the harm done to health during smogs, as Professor Hettche had recalled in his paper.

Assuming that it was not possible to avoid this transformation in the atmosphere when meteorological conditions were favourable to it, the only action that could be taken to avoid the danger was to limit to the maximum the emission of sulphur gas into the air.

Now, as far as fuel oil [mazout] heating was concerned, statistics proved that the combustion of coal in domestic fires and for industrial purposes in the Department of the Seine had fallen, since 1957, while that of fuel oil had risen. But, in two years: from the winter of 1956–57 to the winter of 1958–59, the average level of smoke had risen by 4 per cent in the centre of Paris and by 10 per cent in the 16th Arrondisement, while that of SO_2 had risen by 27 per cent and 43 per cent respectively.

Therefore one could conclude, with all certainty, that the more rapid rise of sulphur pollution, compared with particulate pollution, was due to the development of oil heating.

This confirmed in practice what could be presumed by calculation. In effect for 1,000 calories from French coal (which contained about 1 per cent of sulphur), 1 gram of sulphur was emitted into the atmosphere, whereas domestic fuel oil, for the same number of calories, emitted 1.6 gram.

Session V—Research and International Co-operation

Review by Dr. C. Forrester, Rapporteur

Dr. Forrester said:

In reviewing the nineteen papers presented to you for discussion this morning, I have adopted the view that we should consider first the present position of research in this field in relation to our ultimate target—clean air—and, in furtherance of that aim, consider also the extent to which international co-operation in research should be promoted, and can be achieved.

The picture drawn for us in the paper by Mr. Buxell, summarises the conclusions and recommendations of two very important meetings, both held in November 1957, namely:

A. the First International Conference on Public Health Aspects of Air Pollution
B. the Fifth Meeting of the Expert Committee on Environmental Sanitation of the World Health Organization.

The former emphasised the serious lack of sufficient *demonstrable* proof of adverse effects on the health of nearly all types of living things and of quantitative relevent information, along with the consequent need for establishing pathological and diagnostic criteria. Dr. Burn has just referred to this aspect.

In spite of these lacks, and of the Conference's opinion that further research is urgently needed on the relationship between air pollution and life of all kinds, there is sufficient information for a start to be made on control, as indeed it has been made in several countries. We in Britain have started to control the atmospheric litter lout.

The Expert Committee's recommendations include the setting up of advisory councils to advise governments and watch the results of national efforts. It gives a list of eight specific subjects for research. Study of that list makes it clear that the subject of the relationship between air pollution and health (of all living things, except perhaps fish!) is a very complex one, a field of investigation in which it is very difficult to draw confident conclusions.

Mr. Buxell goes on to quote:

> " the current status of knowledge is inadequate and ill-distributed, and does not permit the establishment of standards of what levels of concentration are safe to man."

The Expert Committee recommended that institutes of higher learning, and the appropriate international and governmental agencies, should be encouraged to undertake research in solving these more recalcitrant problems.

Some of the " current status of knowledge " referred to in Mr. Buxell's paper is presented in the other papers assigned to this session. Clifton, Kerridge, Pemberton, Moulds and Donoghue, give us an important record relating to bronchitis in Sheffield during smog periods. Mr. Darley of the University of California, gives us corresponding information about damage to plant life; and it is interesting to note that damage by fluorine is in the picture, a point that fuel users, and particularly coal users, may be prone to forget. Air pollution does not come from fuels only.

The paper from Dr. Nose, gives us comparative information about community health in two cities in Japan, where pollution in one of the two cities is attributed largely to the consumption of coal, the other city using little coal and being relatively free from pollution. The data clearly supports the claim that air pollution and ill-health go hand in hand.

A similar paper, comes from Italy, and is presented by Professor Petrilli, of Genoa, who refers to the difficulties experienced in presenting a picture of the dangers due to pollution. Work in Italy, he says, does not yet bear out the conclusions reached in Britain, in spite of there being similar pollution. This relates to work on bronchitis.

In yet another paper in the same field, Messrs. Waller and Commins give us records of concentrations of sulphur dioxide and of smoke in London during smog incidents, drawing some interesting conclusions relating the change of ratios between those two concentrations to position of source of pollution and direction of wind.

Professor Riasanov's contribution, just received, is particularly welcome, offering as it does valuable suggestions from the U.S.S.R. for specific fields of research, and claiming the establishment of two indices of diagnosis—maximum permissible one-time or single concentration and maximum permissible average daily concentration of pollutants. Professor Riasanov also gives a table of suggested indices for 30 pollutants derived by himself and his colleagues.

Dr. Reif, of Boston, Massachusetts, deals with the hazards of tobacco smoking and also with pollution from atomic bomb fall-out material and especially strontium-90 and its relation to lung cancer, the only common form of cancer that is rapidly increasing in most countries. The continuing uncertainty of the conclusions regarding smoking should be noted, as well as Dr. Reif's statement that the powerful carcinogenic effect of cigarette smoke tends to overshadow the effects of air pollution.

So far as *radio active fall-out* is concerned it seems clear that we do not have enough conclusive evidence to be able to form technically sound conclusions on this still controversial subject. Dr. Reif's concise paper presents an interesting mass of facts showing the still speculative nature of the differing views.

We have three papers on the emission of pollutants from domestic consumption of fuels in Britain and one on the same subject from Germany, from Messrs. Dickinson and Kimber (the former dealing more with methods and the latter with actual results) from Mr. Andrew of the (British) Gas Council, and from Herren Lenhart and Thieme, of Germany, dealing with the problems involved in operating small coal-fired stoves. It is interesting to note the use of an optical instrument for measuring smoke density.

A point emphasized by the Gas Council contributions is the fact that town gas in Britain is inevitably almost sulphur-free. Although, as Rapporteur, I am probably not expected, perhaps not strictly speaking allowed, to interpolate my own remarks, I risk doing so here on one point, namely, that not only is town gas virtually sulphur-free but any other gas and indeed any synthetic liquid product of *complete* gasification of coal is almost certain to be sulphur-free. This might be a matter of considerable importance if, as is likely, chemical engineering methods for using coal are adopted more and more in the future.

Herren Harth and Seidl's contribution from Germany gives us strong support for the case of international co-operation, especially in respect of documentation, and offers useful suggestions. Mr. Isaac's paper, from King's College, Newcastle, is in similar vein and Dr. Kelm's paper shows how local authorities in Germany are tackling the problem of control, and offers suggestions that should be considered by those favouring co-ordination of effort. A point that is not perhaps specifically brought out, though implied, in the papers before us is the risk of insufficient co-operation between individual workers within a nation as well as insufficient co-ordination and dissemination of knowledge within the nation as distinct from internationally. Mr. Isaac strongly supports the views expressed in Mr. Buxell's contribution, on the matter of swifter and wider dissemination of knowledge.

Messrs. Heiman and Stern give a concise account of the current status of air pollution research in the U.S.A. The cost of this work is met largely from public funds. The authors do not state how much public money is allocated for this.

The remaining papers are more specific in the ground covered. Dr. Scorer's paper on photographic methods, while purporting quite properly to expound the thesis of photography as a valuable aid in research on air pollution, incidentally offers the additional attraction of a source of much-needed material for convincing propaganda, an equally valuable tool in the international fight for clean air.

The subject of inversion is always difficult for the less knowledgeable worker in this field to understand and the paper by Mr. Meade is an excellent instructional contribution.

Mr. Spurr offers a contribution on the even more difficult mathematical subject of the theory of plumes and heat rates in relation to penetration of inversions. Two papers, one by Messrs. Dickinson and Kimber already referred to, the other by Messrs. Wolf, Von Hohenleiten and Gordon, of Baltimore, deal with experimental methods for collection of dust and fly ash at generating stations. The high capital cost of the equipment, from 3 to 5 per cent of the total cost of the plant, is emphasized by the Baltimore authors.

Finally, the composite message I think we gather from the papers before us this morning is somewhat as follows:

that a mass of research work is being done throughout the world, in many countries;

that sufficient results have been obtained to enable a substantial start to be made on control, where it has not yet been started;

that there remain important problems about which opinion is still divided, particularly in the medical field;

that it is too early for us to be dogmatic about the hazards of atomic fall-out;

that a lot remains to be done in devising and testing diagnostic methods, as well as in the standardization of methods of measurement of all kinds, and of terminology;

that the international dissemination of results and documentation should be both quicker and better co-ordinated.

Discussion

A. C. Stern (U.S. Public Health Service, United States of America), in opening the discussion said that with such a large number of papers to discuss, he had chosen one as the point of departure. The paper by Mr. P. C. G. Isaac, " Some Thoughts on International Co-operation in Air Pollution Research " rather well summarized five or six other papers which had been presented in that session or earlier, all bearing on various aspects of international co-operation.

Therefore, he would take the seven minutes which had been allotted him to cover the two aspects which were raised, namely international co-operation at the governmental level and international co-operation at the non-governmental level.

In the United States they had had international co-operation along both of their borders. They co-operated with the government of Mexico when the United States Public Health Service and the Bureau of Mines rendered assistance at the time of the Poza Rica incident in Mexico.

They had worked co-operatively with Canada on two major international air pollution problems. The best publicized was the Trail Smelter case involving air pollution originating in the Province of British Columbia, and causing damage in the State of Washington. An extensive report was published by their International Joint Commission. (Canada and the United States.)

The International Joint Commission had recently completed its field work on the study of air pollution along the Detroit river, involving the State of Michigan and the Province of Ontario, the report, of which, had just come from the printer.

In the United States, therefore, they had not waited for a world organization to initiate co-operation between the United States and its two border countries. This was well under way. They did, however, recognize that problems of international co-operation were not dissimilar to the problems they had in co-operation among their fifty sovereign states, many of which had problems with their neighbours. In this area, much remained to be done.

Although they strongly encouraged greater World Health Organization participation in air pollution matters, they would not like to see it done exclusively on a European regional basis, because that would exclude the United States from the deliberations. Nor did they believe that international co-operation in the field should be limited to the subject of health alone, but rather should encompass all aspects of air pollution —agricultural, livestock and so forth, with which they were concerned.

There were a number of areas of investigation and co-operation which were best handled by non-governmental groups. Their feeling in the United States was that wherever an activity might be effectively handled by a professional or a civilian group it should be done that way. They therefore applauded the suggestion in Mr. Isaac's paper for the initiation of an international congress on air pollution, to be formed with the national associations in the several countries as constituent bodies. Mr. Stern suggested that the conference take steps to initiate such an organization.

In the United States, the Air Pollution Control Association was already effectively an international body embracing Canada, the United States and Mexico. In fact, the present organization of the Association dated from a meeting held in Montreal, Canada. There were, however, other American professional organizations active in this field.

The American Chemical Society held annual symposia on atmospheric chemistry. The American Industrial Hygiene Association was producing an Air Pollution Manual. The American Public Health Association and the American Society for Testing Materials were both attempting to standardize test methods for air pollutants, as they had previously done for water pollutants. The American Society of Mechanical Engineers was revising its Model Air Pollution Law and assembling data on air pollution research in the United States.

Mr. Isaac's discussion of the need for an international journal reminded him of the remarks made on the previous day by Dr. Parker when he was discussing the desire for standardization of deposit gauge design. Mr. Stern interpreted Dr. Parker's remarks to mean that it was desirable to standardize on a deposit gauge so long as we were sure that the one we standardized on was the British model. In the several nations there were already adequate national journals for the dissemination of the national product. It therefore might be well for the time being to consider the Journal of Air Pollution as the British journal in this field rather than as *the* international journal.

He believed that we ran the risk of losing accessability of air pollution literature if we attempted to put too much of it into journals which were not well circulated to libraries around the world. The more literature we could get into journals (such as those of the established Chemical and Engineering Societies) which were well stocked in libraries everywhere the more accessible our literature would be for those who wished to find it.

Finally he came to the subject of abstracting. It was suggested that each nation abstract its own journals. This was an excellent suggestion if all nations would do so. But as long as some of them did not, it would be necessary for the remainder to continue to abstract in the literature of other nations to prevent a serious gap from existing. In other words, if out of any ten nations, seven did national abstracting and three did not, all the other seven had to continue to abstract in the languages and journals of the other nations. If an international congress on air pollution was organized, a primary task for it would be to initiate international abstracting. They wished it well.

Dr. F. Hartogensis (Research Institute for Public Health Engineering T.N.O., Netherlands), said, that all agreed that international co-operation was necessary and that conferences like the Society's or the conference of Milano in 1957 were very useful. But it was difficult to have a good discussion and to reach certain conclusions when so many delegates were present. He felt that, besides these conferences, meetings of smaller groups (like those as organized by the Organization for European Economic Co-operation in Paris in 1957 and 1959) were also necessary. He strongly supported the suggestion, made by Mr. Isaac in his paper, that an international association for clean air ought to be set up, in which professional and other national organizations could collaborate.

Many series of determinations of certain air pollutants, such as smoke, dust, sulphur dioxide and hydrogen fluoride had been carried out in the Netherlands, using the British Standard Deposit Gauge and several other methods, and were described in the contribution of Bergshoeff and Brasser to the Milan conference. Several effects of air pollution on plants and on men had been studied or were being studied, as well as technical measures for preventing air pollution. A more detailed description would be given in the near future.

Miss Dorothy Boyd (Individual Member), said her interest in air pollution had been aroused as the result of filth deposited on her freshly painted house during a few day's murk. Having read of the success of Manchester's first smokeless zone and of how St. Louis, Missouri had tackled air pollution in 1939, she soon found that half the smoke generated in this country came from the domestic chimney.

For the benefit of visitors from overseas, she called attention to the long established method of heating private dwellings in this country by open fires using bituminous coal, and to the efforts being made to encourage the use of smokeless fuels, some of which were being used in the appliances in the exhibition.

She urged local authorities to press forward with public education on this matter and to stress that smokeless fuels burned in the right appliances correctly fitted saved both money and work.

She deplored that many smokeless fuels were said to burn in the old-fashioned stool-bottom fire, because although it was true, it was only half the story. So used, they were wasteful, and some of the extra heat generated would escape up the chimney and burn out the firebricks; so costs would mount instead of decrease and there would be a genuine cause of complaint.

From the national point of view Miss Boyd referred to the estimate of the Beaver Committee that air pollution cost the country some £250 million per annum, 80 per cent of which (viz. £200 million) could be saved. It did not appear to be so widely recognized that whilst the Clean Air Bill was going through the House of Commons it was estimated that the cost of implementing the findings of the Beaver Committee in full would amount to £50 million per annum over 10–15 years. Taking the highest figure at £750 million the cost could be recovered, by saving £200 million per annum in under four years, and continue to pay dividends in improved health and amenities. That was an investment of the highest order, and it was interesting to note that Sir Ewart Smith had arrived at the same conclusion by a slightly different route in his address to the Institution of Mechanical Engineers. The address was reported and commented upon in No. 102 (Summer 1957) of *Smokeless Air.*

During the past year there had been meetings of the Society and the Institute of Fuel to consider technical difficulties experienced by industry in complying with the Clean Air Act and Regulations.

Whilst the elimination of dark smoke appeared to have been achieved to a large extent, there were many outstanding difficulties and whilst technically, solutions were available to most smoke, dust and grit problems, the cost was often quite uneconomic and would increase the price of the end product.

It was here, Miss Boyd suggested, that the Government of this country, or any country truly intent on ridding the air of pollution, in view of the great social and economic benefits to be achieved, might well investigate the possibility of subsidising industries with particular difficulties.

From the international point of view increasing anxiety was being experienced concerning the growing danger to humanity from the fall-out of radio-active debris following nuclear explosions; there were serious differences of opinion between scientists as to the rate of fall-out.

In Britain, the power plant Zeta was being used for research into the peaceful uses of atomic energy, and as long ago as 1952, the late Lord Cherwell, speaking in the House of Lords on atomic energy research, said that, if the destructive forces let loose in the hydrogen bomb could be harnessed for the benefit of man, one pint of heavy water could be made to give heat equivalent to burning ten thousand tons of coal, and the problem of world reserves of energy would appear to have been solved for all time.

Miss Boyd concluded by commending similar research to all countries, for, working together, much could be achieved towards making the atmosphere of the world as pure as when it was created.

F. J. Redstone (Chief Public Health Inspector, Corporation of Bristol), pointed out that the Chairman had emphasized that the session was concerned with co-operation and, of course, that was needed in great measure between all those responsible for the administration of clean air legislation and those who had to comply with it. There was now to be seen a great preparedness on international, national and local levels to exchange information on ways and means to ensure and maintain purity of the air and that was further in evidence by the scientific approach which was now being made in tackling intractable problems.

During the Conference the delegates had been exhorted to be more scientific but Mr. Redstone felt he should remark that very largely the momentum created in the movement for clean air had, over the years, been actuated mainly by people who knew what they were complaining about but did not necessarily know all the answers.

Atmospheric pollution was not a joking matter but he was amused a few days previously to hear of a man who said to another, " My wife is extremely interested in clean air, in fact we are now using nothing but hopeless fuels " and he went on to say that she was now demanding an emotion heater! The point he wished to make was that there was still need to encourage emotion from the body of the hall as well as scientific papers from the platform. Each had a place in the scheme of things and he was sure that in this way we should eventually secure solutions which were not only scientific but would give satisfaction to all concerned.

Dr. W. C. Turner (Medical Officer of Health, Metropolitan Borough of Poplar), said they had been presented with a most interesting series of papers which were worthy of the closest study. A statistical survey by the London County Council of the mortality and morbidity from cardio-respiratory causes during the 1952 smog had shown a strong correlation between chronic bronchitis and smoke, but the correlation with sulphur dioxide was not significant; neither of these results had been expected. These findings had since been confirmed by the M.R.C. Atmospheric Pollution Research team.

Mr. Meade's paper drew attention to the effect of inversions; these occurred very frequently during the autumn and winter and coincided with the maximum output of domestic smoke, all of which in towns was trapped near the ground below the inversion. We knew that hot plumes from tall chimneys penetrated most of these inversions, but what of gas-washed plumes? Sulphur removal fell far short of 100 per cent so that what remained in the plume was dilute sulphuric acid, which was also trapped below the inversion, owing to the loss of buoyancy due to cooling of the plume by the evaporation of the water in it. Could there be any excuse for continuing this nuisance during smogs? If the answer was " No " could there by any justification for the continuation of the process during the rest of the year when the cleansing effects of the atmosphere were so much more efficient?

As might be expected from the home of Pavlov, Professor Riasanov had introduced us to a fascinating exploitation of the " conditioned reflex " as a research tool, with great possibilities. We had, however, to be careful not to interpret any physiological response as necessarily indicating either toxicity or harm to the human organism. Research was still necessary, but as Dr. Waller had said, on occasion the concentration of smoke in the atmosphere had ruined experiments by blocking filters; let us get on and remove the obvious pollution.

Dr. Turner said he had that morning been handed a copy of a very old statute of 1853—it related to London and required that furnaces should be so constructed and operated as to consume their own smoke—fines for contravention were up to five pounds (£5) and doubled for each succeeding offence! On behalf of Mr. C. E. C. Townsend, present as a representative of the Port of London Authority, he had pleasure in handing it to the Chairman for the Archives of the Society.

Dr. H. de Graaf (Food Inspection Department, Rotterdam, Netherlands), wished to comment on the paper by Mr. Buxell urging intensified research on methods reducing pollutants discharged from special processes.

He pointed to the removal of SO_2 from stacks of electricity plants; although in Fulham and Battersea a beginning was made, Fulham died out and Battersea was as far as he knew the only plant where the wet process was still carried on. That no other plants were changing to this method proved that it was still economically unsatisfactory.

Although research in this subject was going on in Essen, Germany and in Russia, the problem of SO_2 removal was still far from solved and Dr. de Graaf stressed the urge for intensified research to find an economically responsible means of recovering SO_2 from the stacks of these and other plants which dissipated SO_2 in the atmosphere on a large scale.

Dr. A. Parker (Royal Society of Health), said that he agreed with much of Mr. Buxwell's paper, which quoted from the report of the World Health Organization's Expert Committee on Air Pollution, of which he (Dr. Parker) had the honour to be the chairman. International co-operation in efforts to solve the problems of air pollution was certainly desirable. The World Health Organization could assist materially by acting as a " catalyst " in encouraging co-operation, but over-centralization by the WHO or any other similar organization should be avoided as over-centralization in large organizations often led to delays. Direct personal contact between investigators in different parts of the world was the type of co-operation that would be most fruitful.

Care was always needed in drawing conclusions from statistics, especially when many different environmental factors were involved. It had been stressed that the death rate from respiratory disease was much greater in Great Britain than in certain other European countries; but it could not yet be definitely concluded that this difference was mainly due to the effect of air pollution. In addition to differences in environment, there may or may not have been differences in diagnosis. In this connection, it was interesting to observe that the expectation of life at birth was about the same in all the western European countries and in the United States and Canada.

Dr. W. R. Martine (Administrative Medical Officer of Health, General Purposes, City of Birmingham) said that, as a Medical Officer in the field of Public Health, he was concerned with the living, not the dead. For that reason he wished to congratulate those who had contributed from the University of Sheffield. To stress the importance of morbidity, as distinct from mortality, as they had done, put the problem of smoke and health in its true perspective.

People might not die from the effects of chronic respiratory disease until long after they had been removed from our black areas or had been rehoused under relatively ideal conditions in the course of redevelopment in our urban areas. The important point was that there had been earlier lung damage, leaving a devitalized lung and heart incapable of withstanding some later acute illness which would not necessarily have been fatal in a person with healthy lungs.

In Birmingham, their investigations of the medical grounds put forward with applications for municipal houses and flats had certainly brought this morbidity to the fore-front. Over the last six years, more than 30 per cent of their annual three to four thousand new applicants had claimed priority because of respiratory disease of some kind in their families. While he did not suggest that atmospheric pollution provided the sole reason, it was nevertheless significant that these families were living at the time of application, or had previously lived, under overcrowded conditions in what, from the records of deposited soot and atmospheric sulphur, are certainly their " blacker areas ".

That being so were there not the strongest reasons for Local Authorities to press on with Smoke Control and for the Ministry to simplify the present unwieldy and protracted procedure whereby a Smoke Control Area Order might be made?

D. S. Wilson (Central Electricity Generating Board), said that he wished to refer to the paper by Mr. Andrews of the Gas Council on " The Emission of Oxides of Sulphur from Domestic Appliances." The paper stated that " it had not been possible to find reliable evidence on the proportions of SO_2 and SO_3 in the combustion products from various fuels ". Some years ago it had been realized by his colleagues with the late Fuel Research Station, that it was possible that the relatively small amounts of SO_3 which existed in association with the SO_2 in flue gases arising from the combustion of sulphur containing fuels could be as of much significance as the greater quantity of SO_2. Measurements had therefore been separately made of these two constituents in the flue gases arising from the combustion of solid and liquid fuels, including the gases from domestic appliances burning coal and coke. The results had been published* as had also work on the same subject by other workers.

Mr. Wilson said that he could partly answer the question asked by Councillor Mrs. Allan, referring to the emissions from various domestic appliances. He thought that this question spotlighted a significant omission from the paper by Mr. Watson since although the title of the paper referred to " domestic appliances ", it made no mention of the most widely used domestic gas appliance, i.e. a gas cooker. He recalled that the SO_2 meter designed by Cummings and Redfearn and referred to in their paper, had been calibrated to measure the levels of SO_2 which were normally found in industrial areas. When these instruments had been taken into kitchens which contained lighted gas cookers, the instruments had frequently gone off the scale. This meant that many women working in their kitchens were breathing air which contained higher concentrations of SO_2 than existed in many industrial areas. In his opening remarks, Dr. Burn had mentioned that women between the ages of 15 and 45 suffered more from bronchial ills than did men in the same age group. He would not, however, imply that there was any relation between these two facts.

He supported the remarks of Mr. A. D. Cooper (a speaker from Shell International, in an earlier session) regarding the effects of paraffin stoves for space heating. These appliances, which had greatly grown in popularity in the United Kingdom in recent years, had been shown not to give high SO_2 concentrations in the air of rooms where adequate ventilation was available. He stressed, however, the need for adequate ventilation.

A. C. Hazel (Hurseal Group), said he felt that the vast majority of people attending the Conference were not really deeply interested in scientific papers explaining the degree of harm that polluted air did to the community.

What the audience knew was that it was harmful. The precise degree of harm was incidental and what was wanted was not so much scientific explanation but more action and more propaganda. All attending the Conference knew that a cure was possible—smokeless fuel, be it solid, liquid, gaseous or electric, was available.

The public had the solution in their own hands. What was necessary was more education—the public must be told they have the answer to smog already.

It was a great pity that so many brilliant papers should be written which were all right for a meeting of scientific bodies but had little or no news or propaganda value.

The Clean Air Society should be essentially a body to publicise, and yet only one paper—that by Mr. Marsh—referred to publicity. The newspapers were full of the Motor Show—the Clean Air Conference was not even mentioned—people wanted cars to get into God's fresh air—to get away from dirt and smog whenever possible. Soon the roads would be clogged and polluted. Why not start by making the towns cleaner?

More and more propaganda should be the theme of every Conference. Tell the public two simple truths—polluted air is harmful—the cure as far as the householder is concerned is available. Let each householder do his duty.

Alderman W. L. Dingley (Chairman, Health Committee, Warwickshire County Council), said there was a wealth of fertile brains, but not sufficiently fertile, for many problems in respect of pure air were still unsolved. He hoped all science masters would interest their young students in these unsolved problems, and all local authorities would invite their health inspectors to talk to pupils. Even young students would readily recognise the damage to health and the waste of passing into the atmosphere incompletely burnt fuel, and harmful dirty gases. Also the waste of fuel by discharging the products of combustion at a temperature above that of the outside atmosphere, and the stunting of crops by polluted atmosphere.

The students would not produce economic solutions for some years, but meanwhile the interest created could only help the dissemination and implementation of the present state of knowledge.

Professor Jan Just (State Institute of Hygiene, Poland), in a written contribution discussed the basic principles of the bill on the protection of the atmospheric air against pollution in Poland.

In 1959 the bill on the protection of the atmospheric air from pollution had been drawn up in Poland. The recommendations of the bill were founded on prophylaxis in its widest sense. That was especially so, in relation to the localization of industrial plants, and the distance required between the plants and the housing settlements, or housing quarters of the settlements. The chief recommendations of the bill might be summarized as:

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* Crumley, P. H. and Fletcher, A. W. The Emission of Sulphur Gases from a Domestic Solid Fuel Appliance. J.Inst. Fuel, 1957, **30,** p.628.

1. All the changes in the natural properties and composition of the atmospheric air causing ill effects and discomfort to men and animals, or detrimental to plants and natural resources should be considered as pollution of the atmospheric air. The changes in question were produced by dust, gases, smoke, odours, radiant energy, noise or vibration.
2. The construction plans of new industrial establishments and those connected with the rebuilding or extension of the old ones, should not be approved or carried out without a simultaneous approval and realization of the projects regarding the measures (apparatus, etc.) which should be taken for the purification of gases arising from the works, and discharged in the atmosphere.
3. The limits were set up concerning the maximum allowable concentration of contaminants removed to the atmosphere by industrial plants and namely:
    (a) the content of dust in 1 m^3 of gases liberated to the atmosphere should not exceed 1 g.
    (b) the content of certain gases and steam in 1 m^3 should not exceed:
        Carbon monoxide (CO)—10 g
        Hydrogen sulphide (H_2S)—0.0076 g
        Sulphur dioxide (SO_2)—0.9 g
        Chlorine (Cl_2)—0.23 g
        Hydrochloric acid (HCl)—0.23 g
        Fluorine and its compounds (F)—0.23 g
        Carbon bisulphide (CS_2)—0.1 g
        Nitric oxides (N_2O_5)—0.05–0.15 g
4. Industrial plant, the operation of which induced noxious and discomforting changes in the atmospheric air should be located on the downwind side of the settlement, taking into consideration the prevailing winds. Such a plant should be separated from the buildings and the inhabited area, by a sanitary protection zone i.e. surrounded by a free space, which remained under the noxious and discomforting influence of the industrial establishment.

    In principle the sanitary protection zone should be afforested and not included into the housing construction plans.

    The industrial plants were being divided into five classes. A minimum width of the sanitary protection zone was set up for each class:

    I class—1,000 m
    II class— 500 m
    III class— 300 m
    IV class— 100 m
    V class— 50 m

    The following characteristics of the plant to be taken into consideration:

    (a) kind and amount of production,
    (b) methods of production used,
    (c) ways and degree of the influence of the plant on its surroundings,
    (d) technical equipment of the plant, from the point of view of the protection of the atmospheric air from pollution.
5. The managing board of the industrial plant to be responsible for the proper organization of the measurement of the concentration of injurious substances liberated into the atmosphere, as well as for the control of all appliances and apparatuses used for the purpose.

    The supervision and the periodical control of all artificial means provided to insure a comfortable and healthful atmosphere to fall within the province of the State Sanitary Inspection.

Professor Dr. J. W. Tesch (Municipal Public Health Department, Rotterdam, Netherlands), in a written contribution said that in diseases such as chronic bronchitis we had to consider multiple pathology and multiple aetiology.

In the paper by Clifton *et al* it was stated that low temperatures without increased pollution of the atmosphere were never accompanied by large increases in mortality and morbidity from bronchitis.

However, from Netherlands statistics, indications were derived that period of frost were followed by increases in mortality especially in the older age groups and by cardiovascular and respiratory disease, which showed a peak some weeks after the cold spell.

Concerning the papers by Buxell, Isaac, Harth and Seidl, Dr. Tesch said that as the potential sources increased annually international co-operation, regarding measurements, research in medical mechanisms and technical prevention was a condition for a successful fight against air pollution.

W. Cronin (Electricity Supply Board, Ireland), in a written contribution said that his interest in air pollution was principally concerned with the operation of thermal generating stations burning a variety of fuels. He was therefore, particularly interested in the papers by Meade, Spurr, and Wolf and his associates.

Much research had been recently carried out to ensure that stack emission would be unlikely to cause objectionable atmospheric pollution but, in his view, the mathematical analyses of chimney plume patterns did not give true results for a low efflux velocity to wind velocity ratio; observations showed that, for a large proportion of running time, the plumes could be very dissimilar from the predicted patterns. A series of model tests, recently carried out in University College, Dublin, for the Electricity Supply Board, in a wind tunnel confirmed this view and showed that considerable improvement could be effected by fitting a correctly-designed nozzle on stacks that were designed using a low exist gas velocity.

Mr. Cronin understood that in the design of stacks in Britain and Germany up to 1950, a gas velocity of about 30 feet per second was used. He considered that if a suitably-designed nozzle were fitted to stacks of industrial plants having a low efflux velocity—and thereby increasing the exit velocity to 60–70 feet per second—a considerable improvement would be made in the air pollution situation.

He was surprised that neither the papers nor the exhibition referred to the use of closed circuit television for the observation of the combustion conditions in furnaces and the stack emissions. The installation of a television camera in the furnace and on the roof of industrial plants, where there was centralized supervision, would enable the operator to see the density and condition of the smoke and would guide him in making the necessary adjustments to correct it. This could be very effective in reducing air pollution.

Authors' Reply

Professor Nose commenting on the papers and discussion, addressed the Conference in his own language, as follows:

" It is a well-known fact that in the cities where air is polluted the mortality of diseases of the respiratory system like pneumonia and diseases of the circulatory system like heart disease is high.

" The influence of such air pollution becomes very powerful when the ratio of pollution shows a rapid increase or when the pollution continues for several days. The influence is also known to be serious for patients already suffering from bronchitis or heart disease and for old people as well as infants.

" It does not always follow, however, that many scholars have statistically clarified these chronic facts standing on the epidemiological viewpoint. This report of mine, I think, presents some trustworthy statistical data on this point.

" I have found that the relative mechanism between air pollution and the mortality always stands on a synthetic influence of the predisposition with air pollution containing sulphur dioxide as the central figure. It seems that this relative mechanism has to be separately investigated from the industrial toxication happening in various manufacturing workshops in Japan.

" The reason is this: when the pneumonia and bronchitis mortality in the whole of Japan during the past 59 years is investigated through the epidemiological statistics from the medical and the ecological standpoint, it is clear that the distribution of the pneumonia and bronchitis mortality is generally in the same condition now as in previous years. Its distribution has a close relation to the soil and water quality and the predisposition of individual members of the population has a serious influence on the degree of mortality."

Dr. A. E. Reif wrote that regarding Dr. Forrester's comments that there was continued uncertainty regarding the relation between tobacco smoking and lung cancer, the official position of the relevant health agencies in the United States was quite clear. In a recent article entitled " A Statement of the Public Health Service ", Dr. L. E. Burney, Surgeon General of the United States Public Health Service, states:

" The Public Health Service believes that the following statements are justified by studies to date. 1. The weight of evidence at present implicates smoking as the principal etiological factor in the increased incidence of lung cancer. 2. Cigarette smoking particularly is associated with an increased chance of developing lung cancer. 3. Stopping cigarette smoking even after long exposure is beneficial. . . ." (J.A.M.A. **171:** 1829, 1959).

The American Cancer Society had taken the same position for a number of years, and had tried to keep the public informed. However, thanks to the very effective " scientific " publicity releases of the American tobacco industry, the American public remained confused. As with any complex subject, unanimity doubtless never would be achieved, but recently the number of eminent experts who decried the link between smoking and lung cancer had fallen drastically on his side of the Atlantic.

L. W. Andrew said that it was most gratifying that 4 of the 14 speakers in that particular discussion with 19 papers to choose from, had referred to his paper on " The Emission of Sulphur Oxides " and that he suggested could be taken as indicating a very great interest in that source of atmospheric pollution. The Rapporteur, Dr. Forrester, had stated that towns gas in Great Britain was almost sulphur free and from the point of view of atmospheric pollution this was true. For other reasons it was the target of the Gas Industry to reduce the sulphur even further to say, 10 grains per therm, but at present the average was as stated in the paper about 30 grains per therm.

Councillor Mrs. Allan had asked if portable gas fires were likely to produce harmful concentrations of sulphur oxides and of carbon-dioxide. The short answer to this was no. It should be appreciated that all gas appliances were tested to comply with B.S. requirements before they were approved by the Gas Council, and for example, portable gas fires must be provided with means for limiting the maximum gas rate, and the rated thermal input was limited to 6,000 B.t.u./hr. In addition the Gas Industry complied with Codes of Installation Practice which ensured the correct relation of the heater rating to the size and ventilation of the room.

Mr. Cooper suggested that the figure of 0.9 per cent sulphur in diesel oil should now be 0.5 per cent. The figure of 0.9 per cent was taken from an authoritative source, namely, the Beaver Report published in 1953, and it might be that improvements have been effected since then.

He assured Mr. Wilson that they were familiar with the work carried out at the Fuel Research Station and over many years had co-operated with them on many fuel problems. They were thus aware of the paper to which Mr. Wilson referred by Crumley and Fletcher in which they gave figures for the emission of sulphur oxides by coal and coke from openable stoves and fires. At Watson House they had used the method of analysis developed by Fletcher in which the oxidation of the SO_2 was inhibited by the presence of iso-propyl alcohol. The main difficulty in the determination was the presence of SO_3 mist which was difficult to wash out from the gas. He had looked again at the figures obtained by Crumley and Fletcher and noted that they had stated that the method was not sufficiently accurate at concentrations below five parts per million and that the average sulphur balance in the case of coal was 106 per cent and for coke 99 per cent. Another worker in that field, W. E. Francis, Gas Research Board Communication 64, was not able to confirm the work of Fletcher and in some of his experiments he only obtained a 70 per cent recovery of SO_3. More recently at Watson House, they had obtained recovery figures similar to those of Crumley and Fletcher but it had been found essential to reduce the gas flow rate to 1 cu ft/hr and to incorporate in the apparatus, in addition to the sintered glass plates, a large volume vessel (75cc) to enable the SO_3 mist to settle out completely. They still felt that there was further work to be done on the test method to ensure a completely satisfactory determination of SO_3 in presence of SO_2.

Mr. Wilson had also mentioned that the sulphur dioxide content in the air in kitchens with a gas cooker alight was higher than that normally found in industrial areas and that when the SO_2 meter designed by Cummings and Redfearn was placed in a kitchen, the instrument had frequently gone off the scale i.e. above 0.5 p.p.m.

Attention was directed to the intermittent usage of cookers in practice and the fact that something like 80 per cent of people in the country cooked by gas. They were unaware of any complaints of smell of oxides of sulphur whereas the threshold of smell of SO_2 was accepted as 1 ppm.

P. C. G. Isaac wrote that he was flattered by the attention given to his very slight contribution to the Conference. He wished to reinforce Dr. Forrester's point that there was often insufficient co-operation between research workers even in the same country. Mr. Isaac hoped that the two lists of national research projects (U.K. and Japan) already published by the *International Journal of Air Pollution* and the excellent list issued by the Air Pollution Control Association for the U.S.A. would be followed by others and would assist " intranational " as well as international co-operation.

Mr. Isaac thought that Mr. Stern had been a good deal less than gracious in his remarks about the *International Journal of Air Pollution*. This was already an international journal: it had an American editor and received a substantial proportion of its contributions from the U.S.A. as well as very many from other countries. It was issued by a publisher with a world-wide organization. He was not quite sure that he could accept Mr. Stern's suggestion that papers on air pollution should be published mainly in existing journals devoted to single disciplines. The danger there was that most workers tended to see only those journals concerned with their own discipline. As to abstracting Mr. Isaac would like to draw Mr. Stern's attention to the abstracting service in the field of occupational safety and health recently organized by the International Labour Office through national bodies. This offered a working example of Mr. Isaac's suggested system.

Dr. Parker had emphasized a point which had been implicit, but not sufficiently explicit, in Mr. Isaac's paper, namely that personal contact between individual investigators was vital for healthy research.

Finally, Mr. Isaac hoped that the seed of co-operation would fall on good ground and that in the not too distant future a voluntary international association might be formed.

Dr. Marjorie Clifton, on behalf of her colleagues and herself, said that in reply to Dr. Tesch's contribution mentioning their work, they wished to make it clear that their report was concerned only with immediate changes in morbidity and mortality. Since cold weather always accompanied periods of severe " smog " their separate effects during these episodes could not be distinguished, but they had found, on studying cold spells of equal intensity not accompanied by increased pollution, that there were never such large immediate increases in morbidity. The deaths were more variable at all times. In the climatic conditions obtaining in Sheffield the weather was not sufficiently consistent for them to be able to relate health changes to any occurrence more than a few days earlier, with any confidence. Since periods of frost coincided with the season of prevalence of respiratory infections they should certainly not feel justified in connecting any increase in deaths in Sheffield with cold weather some weeks earlier, though this did not rule out the possibility that there was an association.

SESSION VI

The final conference session, with reviews by the Rapporteurs of Sessions II to V, final general discussion, and a closing survey of the conference as a whole by T. C. Bailey.

Dr. J. S. G. Burnett, who in the absence of Professor A. Semple, Rapporteur, was called on at the last moment to review the session at which he had been Chairman, said: " In Britain there is belated recognition that we have for generations literally been under a cloud, we have decided to take action and are now in the process of implementing this decision. This concerted national action is in substitute for the sporadic voluntary efforts in the past of idealists and people of vision who have recognized the cost of atmospheric pollution to the nation in terms of health, happiness and money.

We have heard that in other countries they have their problems too, some of them apparently of quite old standing while others are associated with the new industrialization and with the build up of road transport in congested areas.

The phrase " atmospheric pollution " is used as a general cover for a great complex of problems whose extent differs, from country to country and from region to region, in origin and in character so that each single problem has to be broken down into its individual parts, each of which have to be separately analysed before the solution can be determined and applied.

In a number of countries it appears that the measurement of pollution and its analysis, also with attempts to determine levels of tolerance, are the present lines of attack, but it is of great interest also to learn of the prospect of a future smokeless zone in Paris.

As opposed to the international character of the papers, the discussion was perhaps somewhat parochial and in the narrower context not very informative, but in its wider implications it is no doubt intriguing to the overseas delegates as an example of the working of British democracy. For those inexperienced in our ways they can be reassured. It is not uncommon for civil servants to appear on a conference platform and be torn to shreds. The speaker's reaction is always the same—a modest, diffident and apologetic recognition of his awareness of the lack of worth and the faults in his own contribution and a return to his department to do precisely as he intended from the very first.

Professor Kaiser's interesting contribution includes a reference to the problems of refuse disposal. In this country as in America the changing habits of the people, with so much food now packed in cardboard containers, cellophane or cans and with the altered heating and working arrangements in most households, whereby the wasting of coal in the shape of cinders is markedly lessened, have combined to change the character of household waste materially. The introduction of smoke control areas is accentuating this change in the affected areas so that household refuse is now not only bulkier and lighter in weight, but has a much lower calorific content and is lacking in ash content. There is a developing problem here associated with the modern way of life. It can be met in a variety of ways and probably the major problem will be recognition of the need to spend more money in order to achieve satisfactory conditions of refuse disposal."

G. Nonhebel (Rapporteur of Session III), said: " The discussions on the Technical Papers in Session III have been on methods of substantially reducing air pollution. We are, however, a large manufacturing nation living in a cool climate: we must, therefore, have furnaces for raising steam and carrying out processes such as steel manufacture and we must heat our buildings and cook. The only way to avoid air pollution from most of these energy consuming operations is to use electricity from atomic power stations in which all the gases are bottled up, but we shall still get dust and fumes emitted from existing electrically heated metallurgical furnaces and we have yet to develop economic methods of smelting ores electrically.

The Conference is gratified to hear that the National Coal Board has decided that they must make it possible for British households to retain their open fires without making smoke by developing special fuels made by treating coal. The new fuels will give flames just like untreated coal, will throw out at least as much heat and will be consistent in quality. They will, however, be appreciably more expensive than the alternative smokeless fuel, coke, but much less bulky. The prosperous will undoubtedly take up these new fuels if they live up to their promise when produced on a large scale, especially if they become fashionable to use. In the discussions the Coal Board is severely criticized for planning to market only one million tons of the new fuels by 1965, since pilot quantities of these fuels will be released next winter for market appreciation. They are also criticized for their slowness in negotiating with the Trade Unions for the replacement of miners' concessionary coal by equivalent quantities of gas or electricity and smokeless fuel, since it will be impossible to establish Smoke Control Areas in many black areas of the country until this is done.

Much emphasis is placed on the need to reduce emission of sulphur oxides by developing effective processes for the removal of sulphur compounds from both oil and coal. Whereas sulphur in oil would be removed and converted into a useful product, that in coal could only be concentrated in the " middlings " and " rejects ". Dr. Lessing would like these to be incinerated together in special power stations equipped with dry processes for the removal of the sulphur oxides from the flue gases.

On the general question of the importance of sulphur dioxide, Dr. Turner thinks that dampness of buildings might be an even greater cause of bronchitis.

The discussion on industrial processes emphasizes the over-riding importance of correct initial design and construction of the plant. It is well known that it is never completely satisfactory to remedy a bad design once it has been built, whether it is a coal-fired furnace, a coke oven, a dust arrestor, or a household grate.

The paper by Wolf and associates in Session V illustrates the amount of work which is now put into the design of power station dust arrestors to ensure that full value is obtained from the costly plant required to secure high efficiency. Nevertheless, performance of all industrial plant falls off unless it is correctly operated and maintained. As an example, the unpleasant and dangerous smoke from diesel vehicles is mostly due to bad maintenance. It is suggested from the U.S.A. that roadworthy tests of vehicles should include a test for smoke emission from diesel engines under heavy load."

Dr. E. T. Wilkins (Rapporteur of Session IV) said: " One of the important conclusions from this Conference seems to me to be that serious air pollution is more world-wide than has been generally recognized. This follows from pollution surveys in several countries showing that there were heavily polluted areas in towns where this would not have been expected. Presumably other areas of high pollution would be revealed if such studies were undertaken more generally.

The Conference has also had something to say on the relationship between the size of a town and the degree of pollution of its air. We have a theoretical study of this in Session IV. We have also had some practical information in the form of an exhibit by the Warren Spring Laboratory of the Department of Scientific and Industrial Research in this Conference Hall. This exhibit shows the observed smoke concentrations at numerous sites in British towns plotted against the population of those towns and those delegates who have studied it will have noticed that the plottings are widely scattered and that there is no obvious difference between the range of concentrations observed in small towns and in large.

If pollution is more widespread than we have previously recognized then it is even more important to know its effects on public health. In this connection the paper to this Conference by the Medical Research Council's team at Sheffield is of special importance because it describes a new and more delicate technique for studying this problem than has hitherto been available and because the application of the technique appears to show that, at least in Sheffield, morbidity is related to normal as well as to high concentrations of pollution. Similar epidemiological studies on an international scale might be of considerable value in assessing the pollution hazard in different countries and perhaps also in disentangling the effects of climate and other parameters on the pollution problem.

For such international investigations the use of standardized methods, as recommended in several of the Conference papers, would be very desirable. In some instances standardization may be difficult: such is likely to be the case for deposit gauges of which many types are in current use. However, for epidemiological studies of respiratory disease deposits are of less significance than the inhalable pollutants and, fortunately, the standardization of instruments for measuring these latter pollutants seems likely to be easier. Already the D.S.I.R. volumetric instrument which measures smoke and sulphur dioxide, and at the same time provides a sample which may be used for the determination of organic carcinogens, has been found satisfactory in several countries and may provide a basis for a standardized international technique.

At these Conferences we generally have interesting and important contributions from the electricity supply industry and this year is no exception. One of the subjects discussed in Session IV was the dissipation of the gases from power station chimneys. We were told it is now possible to measure accurately the instantaneous pollution caused anywhere in the region of a power station, that these measurements could now be correlated with chimney design, and that it was beginning to be possible to design a chinmey to give any desired dissipation of the gases. Thus, if we are satisfied with a maximum sulphur dioxide concentration of 30 p.p.h.m. under average conditions of weather then a chimney 300 ft high may suffice. If we require a maximum concentration of 5 p.p.h.m. that, too, is possible, but it will require a chimney which is taller and much more costly. The question is: for what degree of pollution should the chimneys be designed ? This is a difficult question to which an answer must be given and it is interesting to note that the paper from the U.S.S.R. includes suggested values for the maximum allowable concentrations of sulphur dioxide and many other pollutants."

Dr. C. Forrester (Rapporteur of Session V) said: " When I undertook this duty I feared that there would be little time between the morning's discussion and this afternoon's review of the proceedings of the Conference for me to be able to marshal my thoughts and commit some of them to paper for presenting to you. The striking feature of Session V however is the comparative absence of dissension and disagreement on the main points offered by those presenting papers. Fortunately we did have a few divergent views to ponder over, and the session proved to be a stimulating one.

In presenting my summary this morning I accepted from the Papers a composite message consisting of six theses. For the sake of those who may have been more personally concerned in the business of other sessions and who, consequently, may not have been present this morning, I shall repeat them at the end of this commentary.

I shall deal first with a few points which may be considered as bordering on dissension.

Mr. Cooper, of Shell International Petroleum Co., Ltd., rightly drew attention to possible confusion regarding sulphur contents of various fuels, and especially those derived from petroleum. He incidentally touched on a point of terminology, though possibly not the kind of terminology the other speakers had in mind. He pointed out that Fuel Oil such as is referred to in the Gas Council Table I is a residual fuel. Such a product is bound, of course, to contain the part-accumulated sulphur from the original raw material. He might have pointed out, and the Table might well have shown, that there are other lighter fuel oils that contain very much less sulphur, especially those fuel oils (not " heavy ") more generally used in domestic appliances.

He referred to Miss Boyd's question about contamination by carbon dioxide from a kerosene-burning appliance for heating a room. Mr. Wilson added to the interest of this point by referring to the gas cooker in the kitchen. He referred to sulphur dioxide content in the kitchen from the same source. *The carbon dioxide* content must completely outweigh that from a kerosene heater, a point not noticed by either speaker.

Returning to Mr. Cooper's mildly voiced complaint about the implied strictures on the oil industry, I think most of those who know anything about petroleum technology will agree with his statement about the extremely difficult problem of removing sulphur from the distillates, and the industry's continuing efforts in this field. Such work constitutes an important part of the total research on air pollution.

Mr. Wilson reminded us of an important result arising from some earlier work, tending to show that a very small amount of sulphur trioxide may be more dangerous to health than a much larger amount of sulphur dioxide. This impinges on the work on gas washing and shows us how complicated is the field of air pollution research.

There was some disagreement about the claim that tall chimney stacks ensure that the offending plume will be able to pierce an inversion layer. Here is another piece of evidence of the uncertain state we still are in in respect of research. The whole subject of fluid mechanics is an extremely difficult one for the researcher on air pollution and the dispersal of gaseous effluents. But, gas washing or no gas washing, we take away from this conference the slogan " The higher the chimney the better ".

In this session stressing difficulties facing the medical research workers it was particularly pleasing to receive, even at the last moment, such a stimulating contribution from the U.S.R.R., offering what might be called a new tool—two indices of permissible concentration. Its author, Professor Riasanov, in paying a tribute from his country to Britain for its pioneer work in air pollution research and expressing thanks for the large amount of data collected, and made available, provided a good example of the kind of international co-operation and co-ordination of effort that we appear to be aiming at. He underlined this when offering fullest possible co-operation from his country.

Dr. Parker gave us two good examples of the importance of correct terminology when defining a *Committee*, and in giving his maid's use of the word *suspicion*. Mr. Redstone gave us two more, when he referred to *hopeless fuels* and *emotion heaters*. But Dr. Parker's more important contribution was his warning of the danger of world organizations not leaving the actual work to the existing research workers, and his plea that a world organization should concentrate on being a catalyst.

I come now to the question asked this morning: *Where do we go from here ?*

Two speakers made an appeal for less research work and more publicity. I confess to a personal feeling of sympathy with the positive aspect of their appeals. We *Must* have publicity. The generation that is growing up will probably not know, from personal experience, what we older people do of air pollution. We must therefore guard against their innocent ignorance resulting in a relapse.

I think the concensus of opinion this morning was in favour of the recommendations of the two meetings of 1957 enumerated by Mr. Buxell and added to by Mr. Isaac. Here, then, are the six theses I referred to in my opening remarks.

> There is a mass of research work being done in many countries throughout the world.
>
> Sufficient results have been obtained to enable a substantial and vigorous start to be made on control where such a start has not been made.
>
> There remain important problems about which opinion is still divided, particularly in the medical field.
>
> It is too early for us to be dogmatic about the hazards of atomic fall-out.
>
> A lot remains to be done in devising and testing diagnostic methods, as well as in the standardization of methods of measurements of all kinds and of terminology.
>
> The international dissemination of results and documentation should be both quicker and better co-ordinated.

Dr. Parker's quoted definition of a Committee was, if I got it correctly, a group of people who have been unable to do something and meet to decide that nothing can be done. I am sure I am not alone in expressing a confident hope that something *will* be done.

Discussion

Councillor G. Evans, (Birmingham City Council) said that in addition to the existing Smoke Control Areas already created under the Clean Air Act, Birmingham City Council had accepted and approved proposals of the Health Committee of a phased programme for making the whole of the 51,147 acres of Birmingham into a vast smoke control area within fifteen years. This would involve adaptations, conversions or renewals to thousands of fireplaces in approximately 255,184 dwellings, at an estimated nett cost to the City Council of £1,639,817.

Within this fifteen year's programme, it was anticipated that separate Smoke Control Area Orders covering the 1,384 acres, comprising the five redevelopment areas, could be made. Thereby, on a progressive basis the 32,000 dwellings originally occupying this acreage with old fashioned coal burning grates, would be replaced by modern dwellings capable of being heated smokelessly. When the conference was asked " where do we go from here ?" he suggested that the outline of the Birmingham policy which he had given showed that we were progressing on the main task of abating air pollution with the utmost seriousness.

Councillor W. A. N. Jones (Birmingham City Council) said that the International Jubilee Conference for Clean Air had most certainly presented a wonderful opportunity of co-operation. Indeed, the many papers presented showed many complex problems which only the most intimate research and correlation of evidence could help us to solve. Therefore, we should grasp with both hands the opportunity presented to us.

There was no doubt that with the good offices of the World Health Organization the International movement for Clean Air could be a great force in the world of preventive medicine.

He sincerely trusted that the future would see U.S.A., Russia, Great Britain and the many other member countries of the World Health Organization meeting together for a Summit Conference to really make international clean air in all respects a reality.

Professor E. R. Kaiser (University of New York) said that as it would probably be the last time any of the Chairmen would call on him, he would like to express thanks for the fine Conference, delightful Receptions and for the kindness that had been shown to him.

He said that he would like to comment on stoves and open fires just for a moment. Someone had asked in a previous session about smokeless stoves that burned their own smoke. In America the Battelle Institute and Bituminous Coal Research, Inc., had developed one several years ago, employing magazine feeding, secondary air and a gradual devolitalization of the coal. He was sure that Professor Thring knew about it. Professor Kaiser said that much against his will he had been charmed while in Britain by the open fire. Nevertheless, it must have serious limitations because so many English, Scottish and Irish people who had migrated to America had left behind this wonderful device, and had adopted central heating. Britain might well be advised to go towards central or even district heating, as it would help in Britain's air pollution problem. Surprisingly, he said, one quickly

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becomes accustomed to central heating and only a twinge of nostalgia remains for the open fire.

More seriously, on the respiratory ailments, he was sure they were not caused entirely by air pollution. There might be some element in heating or comfort, which if investigated along with air pollution, might result in an integrated proposition, which he believed would help with respect to disease as well as with air pollution.

On cleaning gas at the steel works they had quite a large programme in the United States, which was sponsored by the American Iron and Steel Institute, with Harvard University. Harvard had developed a continuous filter scheme, using blast furnace slag to make the filter bed to trap the particles of iron oxide coming out of the open hearth furnace. They were very much encouraged about it and were now trying it on a pilot-plant scale.

He did not want to leave anyone with the impression that as a University Professor he was opposed to education of stokers. A stoker had to know about his job. He saluted the British educational scheme for having carried that work on and developed it to a high point, issued certificates and all that, and he blessed them for it. But in looking around the exhibits delegates would have seen new mechanical devices coming along, and so he did not think his point was too badly out of place that in the United States they had pushed the mechanical development side. As he had said on a previous day: " build the brains into the equipment."

On sulphur he wanted to clarify his statement; he was referring to residual fuel oil. It was true gasolene, kerosene and the distillate oils in the United States, were not a sulphur problem. However, the petroleum people he had talked to said they had investigated how to remove sulphur from residual fuel oils, but that it was too expensive as yet. They were working hard on it. The hydrogenation of residual oil by Hydrocarbon Research, Inc., has demonstrated that distillate oils of low sulphur content can be produced economically and that the remaining residual oil after hydrogenation is much lower in sulphur content than the original residual.

He was glad to say that his mention of auto-body incineration had met with prompt interest at the Conference. He had already designed two plants for two different Boroughs since he had been at the Conference. They were sketched for local officials which he was glad to do (without his usual consulting fee !).

On the matter of chimneys, again he wanted to mention that on larger stacks one could not necessarily use a simple rule, such as a stack should be 2½ times the height of the largest neighbouring building, and get by with it in all cases. However, a model of the topography and different stack heights could be tested in a wind tunnel at low velocities to find the influence of the wind currents on the dispersion of the stack effluent

Professor Kaiser said that he wanted to say one last thing. He wanted to come out in defence of the ladies, who prodded men into doing something about air pollution. Their wishes and persistence he thought, were the main driving motive to get men to clean up the air pollution problems by research and invention, as well as legislation.

As one last thought, looking into the future he believed we should think of some of the larger schemes of things. For example, integrated plants that would do our heating through central plants, which would help us in our electric heating, and which might burn refuse and fuels to generate steam and power at the same time.

Councillor L. H. Powell (Lichfield R.D.C.) appealed to the delegates not to allow statistics and scientific data to cloud their minds to the fact that their first duty was to people and not to causes. Whilst the cause of clean air was a good one, it was always better to have the support of public opinion. There were many people, not the least being the mineworkers, who were worried about the effect that the Clean Air Act and the activities of the Society could have on their livelihoods. Clean air had little meaning to a man who spent his working life underground in areas where the disease of pneumoconiosis was not unknown. There was no doubt that smoke in the atmosphere was dangerous to health and there had been some criticism that public opinion had not reacted quickly enough in the matter of clean air. Before we became too critical of public opinion, we should consider other health campaigns which had not been entirely successful such as the clean food, anti-smoking and road safety campaigns. It was necessary not only to have a certain amount of public sympathy, but to have the support and confidence of all the people. This should be the first consideration of the Society which should then recommend strong action if necessary.

Councillor J. Farndale (Hammersmith) pointed out that P. D. Coates and Dr. R. Lessing in their papers made reference to the strength of the Alkali Inspectorate.

This body was still inadequate to deal with all the possible nuisances that could arise through the emission of sulphur oxides, etc.; some of the offensive plants in the highly residential areas should come under the control of local authorities.

The number of Alkali Inspectors at the passing of the Clean Air Act was ten. By the May 1, 1958, tne number was increased to 19. The number was to be further increased during 1959 to a total of 28.

Even with this number there was only one Inspector for the Counties of Essex, Middlesex, and London north of the Thames. Could one Inspector control this large area ?

K. T. Diamond (Coal Merchants' Federation of Wales (Eastern Area) said that as a delegate from Wales he was particularly pleased to hear the reference made by the Rt. Hon. Henry Brooke (Minister for Welsh Affairs) to the part which must be played by solid smokeless fuels in order to achieve the implementation of the Clean Air Act with reasonable speed. The message from Mrs. Charlton, President of the Women's Advisory Council on Solid Fuel, and referred to by the Rt. Hon. the Lord Mayor of London, was also significant.

South Wales was probably the greatest producer of natural and manufactured solid smokeless fuels in the world so that both from the clean air and economic aspect had a vital part to play.

It was not sufficiently realized that in South Wales, apart from Monmouthshire, nearly 90 per cent of the coal supplied by the South Western Division of the National Coal Board, including house coal, was 20 per cent volatile or under (regarded by the Beaver Report as smokeless). That was to say that apart from the authorized smokeless solid fuels little more than 10 per cent of house coal distributed in South Wales was smoke producing and this was scattered in small percentages over a wide area. He firmly believed that in order to get rid of the pollution caused by this small tonnage of smoky coal the quickest way would be for the National Coal Board to replace this at once with low volatile coals. The setting up of smoke control areas in South Wales to cover the widely scattered areas where these high volatile coals go would be expensive, largely unnecessary and would take too long.

Cardiff Corporation had pointed the way by resolving to replace the small tonnage of house coal it used with low volatile solid fuel in their next year's contracts.

South Wales should be encouraged to go on using their low volatile house coals so that as much as possible of their anthracite, dry steam coals and Phurnacite could be sent in to the increasing number of smoke control areas elsewhere.

J. M. von Bergen (Air Pollution Control Association of America) said that as Official Representative of the Air Pollution Control Association of North America, he must compliment and congratulate the officers and the members of this Society and the international delegates to this conference, for a very interesting and knowledgeable series of discussions.

He would take back to the United States a great deal of helpful advice as well as fond memories of a truly impressive reception.

His fellow members of the Board of Directors of the Air Pollution Control Association of North America had instructed him to state that the Air Pollution Control Association, comprising 2,000 control officials, researchers and scientists, had formulated a policy of international co-operation with the eventual objective of taking part in an international commission of air pollution.

He was extremely happy that many of the speakers and delegates had shown interest in forming an international group. He believed that a great deal of good could come from a future interchange of ideas in that very important field.

Speaking as a personal delegate and in view of the fact that he had observed a great deal of interesting give and take between delegates, he said that he would like to take the opportunity of expressing a slight exception to some of the statements by his fellow countryman, Mr. Arthur Stern of the United States Public Health Service.

Mr. Stern had commented on the fact that several groups were quite active in air pollution control work in the United States in addition to the Air Pollution Control Association and that these groups had not yet " shaken down " in arriving at a common denominator of air pollution control requirements.

Mr. von Bergen, for one, was somewhat concerned about the total reliance or acceptability of air pollution control recommendations made by chemical engineers employed by industry and by members of the Association of Public Health officials, for two reasons:—

1. There were approximately 3,000 chemical manufacturing processors in the States, contributing some 7,000 chemicals to the air stream by means of their exhaust stacks. Many of these chemical emissions were toxic, but there were also many which, whilst being non-toxic, were greviously offensive from an odorous standpoint. In order to protect the security of laboriously developed processes most chemical manufacturing engineers would not permit analysis of their exhaust gas emissions. He appreciated the intent of the manufacturing group, but he felt that he must question the desirability of attempting to compromise a good intent with corporate financial interest in reducing costs.
2. The Public Health officials of the United States were extremely competent in their particular work. Their greatest concern, however, was with toxicological problems (as they certainly should be,) but because of this primary interest, they did not put sufficient emphasis on the overall aesthetic aspects of environmental air pollution problems.

Mr. von Bergen said that he would like to further clarify this most important concept. Professor Semple, at the start of the conference, and Mr. Hazell, in that morning's session, commented, along with others, on the important aspect of considering the personal relationships in regard to air pollution. He would like to add his bit by making an ordinary plea for the individual man and the individual woman.

The Conference discussed legislative requirements, dust and mist collection, smoke and evaluation of data. The " Efficiency Group " approach stated: " Don't emit any more pollution than you have to whether it is harmful or not ". The " Rigorous Group " approach stated: " You can emit all the air pollution you like, as long as it is not harmful ".

The average man on the street knew little about statistics, physiological effects or legislative requirements. He was equipped, however, with a notable combination of the most delicate sensitive instruments known to mankind—his eyes, his ears and his nose. He represented public opinion and when he said " it stinks " this statement represented air pollution and something more than the ruffling of statistical reports had to be done.

In some areas something had been done. In the United States was a vast area called Texas. In the last twenty years a huge industrial chemical complex had grown in Harris County along the Houston Ship Canal.

Somewhere in the Texas State Charter was a reference to the control of air pollution. The statement might be best interpreted as " Thou shalt be a good neighbour ". As a result of that appeal for treating a neighbour properly, the Texas Air Pollution Control officials could and would shut down any industrial plant that failed to be a good neighbour because of industrial air pollution. Some plants had been taken into Court because they had been poor neighbours. The consequent results were extremely helpful in assisting other co-operate neighbours to see the " light of day ".

Mr. von Bergen concluded by asking that he might again thank the Society and the delegates for the extremely interesting series of meetings and for the opportunity to express his own thoughts.

P. Draper (Shell-Mex and B.P. Ltd.) in a written contribution said that we should all be grateful to Mr. Meade for his clear description of what may happen to flue gases emitted at different levels into temperature inversion layers which are also at various levels. He considered that the paper made it easier for them all to understand what could and did happen.

Although the author stated that the effects of temperature inversion were often exaggerated he felt sure that they were generally less blamed than they should be for their Air Pollution troubles; in fact, it appeared to him that *under normal temperature conditions* and apart from glaring cases of dangerous emissions there would be practically no need for them to worry about air pollution at all because natural dispersion was wonderfully efficient.

As an example he would quote his recent experience in crossing Waterloo Bridge some almost frosty evenings recently when it had been easy to see a clear cut line at an altitude of about 200 ft between clear sky and the restrained polluted atmosphere. He had for this reason been very intrigued when asked by a local authority in the neighbourhood why they had been receiving telephone calls complaining that the resident's silver was suddenly tarnishing rapidly and he felt reasonably sure that the tarnishing must have been due to the pollution caused by this temperature inversion effect.

In the extreme case of a stable inversion lasting for several days normal flue gas emissions were held down and concentrated hour after hour and with smoky chimneys the familiar black-out used to occur. Even in the absence of smoke, the flue gases accumulated to an undesirable level and it mattered little what fuel was burned or how high the individual chimneys might be unless they were able to push their hot gases through the inversion lid. In such extreme cases the tall power station chimneys of 300 to 400 ft in height might often be the only ones that could do that, which was most desirable on account of the enormous mass of gases involved but this would not apply to those power stations employing water washing and cooling of the gases, as such gases would lack sufficient buoyancy.

Mr. Draper felt that this might be a defeatist attitude but thought it one that might have to be faced up to and might save much wasted effort if it were borne in mind.

W. Hansen (B.P., Germany) said that the especial value of the conference was the clarification of the present position of effects, research and remedies concerning clean air. The papers presented might well be judged as a comprehensive basis for future work. That and the opportunity for personal contact with delegates of other countries were the main values of the meeting. In the speaker's opinion, the number of representatives of burner manufacturers attending was disappointing; in fact only one firm presented a paper.

They knew about the amount of dust and grit emitted by a coal-fired plant; they also had some idea of the character of this emission, though little was known about solid particles in the waste gases of oil-fired plants.

The amount, size and chemical character were dependant upon the fineness of atomization, oil and air mixing, flame size and shape, and especially the cooling rate of the flame gases. The grade of oil employed also played a part.

Quite a number of those factors were influenced by the burner designer, who also constructed or suggested the size, shape and material of the combustion chamber.

It was quite possible that certain burner principles might give especially good or bad results. To get the fullest co-operation of the burner manufacturers in the development scheme for clean waste gases would be worthwhile. It might help to solve the problems and lead to distinct sales advantages for certain types of burners.

From research work in Germany it had been found that obtaining a complete sulphur balance in large oil-fired boiler plants was not easy; only part of the sulphur could be detected in the waste gases as SO_2 and SO_3. Certain types of burner, especially of the two-stage combustion design, were stated to produce waste gases more or less free from SO_2 and SO_3, and that sulphur in the fuel at some stage of the overall combustion process might be present as COS or similar compounds.

These results seemed to suggest that the oil burner itself could influence the emission from the stacks of oil-fired plant. These facts should be drawn to the attention of burner manufacturers in order to stimulate their co-operation.

Professor Dr. J. W. Tesch (Netherlands) said in a written contribution that he wished to congratulate the Society on its initiative in organizing a congress, in which delegates from 30 countries had participated.

The Parliament of Great Britain was considered to be the mother of Parliaments.

Britain's air pollution presented itself as an ugly by-product of the upheaval of the first industrial revolution.

The National Society for Clean Air had already started activities in the last century; in this way acting as the mother of clean air movements in many parts of the globe.

Final Review

T. C. Bailey (Immediate Past President, Institute of Fuel) in a final review of the Conference as a whole, said: " May I first of all express my appreciation of the great compliment which the National Society for Clean Air has paid to the Institute of Fuel by asking me, their Immediate Past President, to review this wonderful Conference.

The aims and objects of your Society are very close to the heart of The Institute of Fuel, and I can assure you that they will remain so. I am confident that practically all of our work in the scientific advancement of fuel technology will be of great service to you in achieving the hopes of everyone here that one day our air will be really clean.

In looking back over the vigorous discussions of the past three days, I think that each one of us must feel a deep debt of gratitude to the National Society for Clean Air for making them possible. The Society, as the oldest body of its kind in the world, is far too well known and respected for any praise of mine to add to its stature. But I think we may well salute the initiative which celebrated the diamond jubilee of the foundation of this Society by bringing together over a thousand experts from all parts of the world to compare notes and share experiences—to see what can be done and indeed has been done in several countries, and to take new heart for the still more formidable tasks that still require doing.

I spoke of the discussions as vigorous, and such they were bound to be after the challenging speech of Dr. Semple, the first rapporteur, which struck the keynote for those which were to follow from the floor and inspired trenchant criticism of the British system of dual control.

Indeed, when one speaker after another began to make such acid remarks about the Alkali Inspector it looked as though we might have forgotten that this was an international conference. We seemed perhaps to be airing our own national, even parochial, points of view when the subject of the session was experience around the world. In fact, however, nothing could be healthier. From the first moment of the general discussion it was apparent that none of you were content to rest on your laurels. Foreign delegates must have been made vividly aware of the difficulties that do arise when responsibilities are shared between local authorities on the one hand and a national inspectorate as yet understaffed.

All of us must have felt very keenly the difficulties of the administrator in creating enthusiasm and sustaining popular interest in clean air when it is evident that some of the major offenders have not, and perhaps cannot as yet, be brought into line with the rest of the community. There are immense difficulties here, as everyone with even a smattering of technical knowledge is aware; but right from the outset the discussions were, I think, entirely constructive. Instead of merely accepting or condemning present conditions, there were several references to a possible regional solution of the problem, and I hope that the powers that be, in studying the proceedings of this conference, will consider the possible benefits of more regional activity whereby groups of local authorities in a single area can pool their experience and their technical knowledge, thus unifying the administration of the Act and at the same time making full use of all the resources of local patriotism among the public. I was reading the other day that 17 local authorities on Tees-side were combining to organize a clean air campaign. Your discussions have shown that this kind of thing is not only desirable for itself but quite essential, too, if this emerging chasm between local and national administration of the Clean Air Act is not to be dangerously widened.

And, another sobering thought: while it is true that we were pioneers here in Britain in passing national legislation, we were also pioneers in creating the pollution in the first place. The National Society for Clean Air has been in existence under different names for six decades; but the problem it was intended to deal with has been with us for well over six centuries.

The Lord Mayor of London told us on Tuesday of the troubles his predecessor had with smoke from coal fires in the year 1280. I notice that he discreetly refrained from mentioning that round about 1300 an artificer who broke the law of the time, and exceeded Ringelmann 2, was hanged. Those of you who are evidently impatient of the administrative delays—in reaching a quick solution of air pollution, may long for the good old days of the thirteenth century.

I don't intend to go into the rights and wrongs of the length of time it takes to create a smoke control area after the proposal has first been made by a local health committee. But when we are impatient—and often rightly so—I do think we must force ourselves to remember that clean air exists, or ought to exist, for human beings, and not the other way round. The aim is not administrative tidiness but public health and wellbeing; and when we find the same exasperatingly wrong-headed objections burning up in the course of the apparently endless task of getting a smoke control area into operation, I think we have to remember that this stubbornness is one of the pillars of British liberty, and has to be respected even where it cannot be approved.

One of the most wrong-headed objections was of course the popular old idea justifiable I suppose about a century ago, that filthy black smoke was a hall-mark of prosperity. Today of course we know that smoke is a waste of good money and good resources. It means that fuel is not doing the work it ought to; and we might even change one hard worked phrase on the subject and give it a new life in a fresh version: " Where there's muck there's waste ".

Industry has now realized this fact to a great extent, and shows a much greater willingness to co-operate in the fight for clean air. The prospects of fighting air pollution in this country are brighter now than ever before.

Legislation is clearly necessary and obviously it must vary from country to country, but the exchange of ideas we have had here this week will probably make for greater uniformity in legislation in the future, as by comparing experience we find which are the better and surer ways of making progress, not only technically, but with the general support of industry and the general public.

Another factor making for uniformity is, of course, the pace at which world industrialization is now being carried out. Countries hitherto largely agricultural or engaged in primary production are building new factories and assuming with them the responsibility for air pollution research, and here I feel that every industrial country has a responsibility to these newly developing countries to give them all the help and " know-how " both technically and legislatively to make sure they do not make the mistakes we older countries have done.

I was greatly impressed, as I think all of you were, by the spontaneous offer by Professor Riazanov to make available to all countries in the world the experience and knowledge of Russian scientists in the field of clean air.

But it is not just a case of the older industrial countries clearing up the past mess and the new ones profiting by their example. Those countries that are already highly industrialized are going to become still more highly industrialized in the next generation. Modern ideas demand higher living standards and modern techniques of production make them possible. But they call for use of more and still more energy. That means more fuel. And more fuel, unless we are careful, means more air pollution, visible or invisible.

It was apparent from many of the papers which followed that first class scholarship is being devoted to the technical problems raised by the use of new fuels, and on a greater scale than ever in the past. Indeed, throughout the three final sessions of the conference, we saw how much is being done on the scientific side—the theoretical and technical studies, the search for precision and generally acceptable standards in measurement, and the new research problems that are coming along. We found ourselves involved in the chemical engineering of the fuel that goes into the boiler and the mathematical and statistical techniques for determining just what comes out of the chimney. And next, it is apparent, we have to turn our attention to new fields—to that " vast and unexplored territory " as it was called yesterday afternoon, where the legislator, the technician, and the public health inspector hand over the torch to the medical man for his advice on the degree of danger, or lack of it, of the pollutants that may remain when the first stage of smoke control is achieved. These three final sessions opened up an apparently endless vista of a search for still more knowledge as the implications of clean air gradually unfold themselves.

And yet we cannot leave the problem there. It is not only the theoretical knowledge we need, but the practical means of putting it into effect. We need, as Dr. Parker said yesterday, the " simple and not too expensive instruments " with which the local authority can measure pollution and the industrialist can check the emission from his chimney—instruments which, even if they are not perfect scientifically, at least do a reasonably good all-round job.

What, however, are the lessons to be gained from this conference? Indeed, in looking back on the profusion of subjects covered and the advice tendered, is it possible to discover any simple conclusions at all? I think it is. It seems to me that there are two principal conclusions to be drawn, though I am sorry to say that they seem to point in different, even perhaps quite contrary directions.

The first conclusion is the immense complexity of the clean air problem. It is complex enough already, and the specialist papers of the later sessions have made very clear that it is going to be much more complex in the future. What started out as a very human desire to get rid of an apparently simple nuisance—

dirty smoke in the atmosphere—has proved to involve many scientific and technical disciplines. We have seen the growing interest of the medical profession in the relationship between filthy air and bad health. We all know that a relationship exists; but in just what does it consist? We may have our opinions and hunches—we may name one factor rather than another because we personally are more aware of it, or because it happens to have attracted more research than other factors. This, for example, is what I suspect has been happening in the case of sulphur. But when we come to try and discover cause and effect with the precision and respect for evidence—all the evidence—that the medical profession demands, we begin to realize how very little we know, and how few facts we are going on, when we start talking about the relations between health and pollution. When our knowledge is more complete we may even find that sulphur is not the frightening bogey it is sometimes made out to be. I am glad that some speakers endeavoured to put this bogey in its proper perspective.

The same sort of thing happens in the case of chimney heights. This question has been raised again and again at this conference; and rightly so, for it is a test case of the ability of the scientist to help the practical man to carry out his duties under the Clean Air Act. Yet no sooner have we used the words " chimney heights " than we are involved in some of the as-yet-unsolved mysteries of meteorology. This was made quite clear in Sir Graham Sutton's most stimulating inaugural address. We have several formulae for calculating chimney heights, we have much rule of thumb practice; but when we look at our chimneys, past, present and future and ask ourselves " is this the height they ought to be "? the answer, I am afraid, is not a scientific one.

Mention was made at one point about the reluctance of some architects and town planners to have chimneys at all for aesthetic reasons. And at the other extreme one speaker mentioned a figure of, I think, 750 feet as the possible desirable height for a chimney in a valley, to give a sure defence against the build-up of smog during a temperature inversion. These are extreme positions, but we all know that within a single local authority there can exist conflicts of opinion on a less dramatic but still serious scale about the right height for a chimney. Sometimes it appears to me that the only solution is the invention of an elastic chimney, which will shoot up and down according to the state of the weather; the condition of the wind and the fuel load factor.

This is perhaps an extreme solution, but it does lead to the second of the conclusions I spoke about. The problem is complex and growing more complicated. And the more complicated it becomes the greater is the need for simplification in practice. In this matter of chimney heights, for example, which may serve as a symbol of dozens of similar problems, there is need at one and the same time to get our facts right—and evidently to collect a great many more facts than we have at present—and yet to present the results in a simple, straightforward formula that is both workable and scientific—which corresponds at one and the same time to both common sense and truth.

In combining these two factors—theoretical research and practical application—we are all going to be helped a great deal by comparing the experience of different countries. This conference has been very much more than a gesture. The foreign papers have, as the discussions showed, opened up new lines of thought to the British delegates; and the British papers have, I trust, been of similar practical value to visitors from abroad. I should like to make an appeal to the National Society for Clean Air not to allow the impetus of this international co-operation to slacken. International conferences of this kind are a good thing in themselves, since we can meet and get to know each other in a friendly and professional way, and help to dissolve some of the misconceptions and misunderstandings that spring up between one country and another.

But this conference is of double value in that it has shown us all how very similar the problems are in different parts of the world. The 70-odd papers submitted this week have shown us that somewhere in the world, someone is probably working on a problem which touches us closely as individuals; and I hope that this exchange of information—and this promise of more information available in the future—will not prove a flash in the pan, but that some means will be devised to keep it flowing, even if it proves impossible to have frequent international meetings of this kind.

We are all aware of the financial waste of air pollution. We should also begin to become aware of the waste of talent if we allow people all over the world to carry out their researches and draw their lessons from experience in isolation from each other, without having a chance to compare notes and modify their conclusions. There are few enough people tackling clean air problems; it is essential that their talents should be used to full advantage.

This exchange of information, such as we have seen it in operation here, is one of the means of bringing order out of chaos, and simplifying the growing complexity of fact and theory. But I think we must be prepared to go a step further, and persuade our various Governments to take an even more direct interest in the day to day working out of clean air problems. Legislation, such as we have in Great Britain, is a beginning. It defines the job to be done, but it does not put the tools into the hands of the men who must do it.

Other countries are likely to find themselves in the same position as and when they introduce national legislation. Some of them will have available a much greater volume of factual information than this country could count on in 1956. We have all been impressed, I think, by the size and the composition of the committee at work in West Germany to accumulate scientific and technological data on which future legislation may be based. And we have seen the French proposal for a completely smokeless town, which will produce so much valuable experience.

But no Government can evade a continuing responsibility, if only because knowledge expands and presents new problems. If a Government wills the long-term aim of clean air on behalf of its people, it must be prepared to will the short-term means—the collation and interpretation of research, the initiation of new research; and, when the results of such research are apparent, the preparation of advice and directives on which we can all act speedily and effectively. If your discussions spur your respective Governments into action they will have been a major and permanent boon to mankind. I have no doubt at all that they will spur each one of us individually to greater effort, now that we have seen how far-flung is the battle-line against pollution, and how great are the battles that have already been won for the cause of clean air.

Index to Authors and Discussion Speakers

Page

Ainsworth, G. ... 248
Andrew, L. W. ... 187, 268

Bailey, T. C. ... 277
Berge, H. ... 120
Von Bergen, J. M. ... 276
Besson, A. ... 122, 261
Böhm, J. ... 63
Boyd, Miss D. ... 264
Bronowski, J. ... 66, 255
Brosset, C. ... 20
Burnett, J. S. G. ... 251, 270
Buxell, J. O. ... 185, 244

Carter, J. H. ... 21
Cheek, F. E. ... 259
Clifton, M. ... 189, 269
Coates, P. D. ... 18, 248
Commins, B. T. ... 236
Cooper, A. D. ... 253
Cooper, Miss P. M. ... 253
Cooper, R. L. ... 72
Cronin, W. ... 267
Cummings, W. G. ... 130

Daniel, G. H. ... 60
Darley, Ellis F. ... 193
Dawson, F. E. ... 23
Delbruyere, R. ... 74
Dhenin, G. W. ... 252
Diamond, K. T. ... 275
Dickinson, R. ... 194, 197
Dingley, W. L. ... 266
Donoghue, J. K. ... 189
Doyle, George J. ... 216
Draper, P. ... 252, 258, 276
Drummond, R. M. ... 246
Duguid, S. N. ... 76

Evans, G. ... 272

Farndale, J. ... 275
Farquharson, G. W. ... 246
Federal Ministry of Labour, Germany ... 25
Forrester, C. ... 262, 271
Frangipane, E. de Fraja ... 133

Gilbert, T. ... 177
Giovanardi, A. ... 133
Gordon, M. B. ... 239
Gough, C. Evelyn ... 245
de Graaf, H. ... 265
Graber, R. C. ... 58
Grindell, D. H. ... 135, 261
Grosso, E. ... 133
Guthmann, K. ... 27, 79, 82

Halliday, E. C. ... 29, 137
Hansen, W. ... 277
Harth, R. ... 200
Hartogensis, F. ... 264
Hayman, R. F. ... 83
Hazel, A. C. ... 266
Heiman, H. ... 201
Hettche, H. O. ... 139
Von Hohenleiten, H. L. ... 239
Humbel, P. ... 255

Page

Institute of Public Health, Japan ... 31, 32, 142
Isaac, P. C. G. ... 203, 269

Jacquest, J. W. ... 85
Jarvis, W. D. ... 248, 254
Johnson, K. R. ... 143
Johnstone, T. ... 252
Jones, W. A. N. ... 246, 258, 272
Just, Jan ... 266

Kaiser, E. R. ... 247, 254, 272
Katz, M. ... 34, 147
Kay, Kingsley ... 86
Kelm, W. ... 204
Kerridge, D. ... 189
Kettner, H. ... 91
Kimber, D. E. ... 194, 197
Kirste, H. ... 153, 154, 261

Lasserre, P. ... 93
Lawson, W. ... 258
Leclerc, E. ... 38
Lees, B. ... 99, 255, 257
Lenhart, K. ... 206
Lessing, R. ... 102, 255
Lindberg, W. ... 40
Lochmanova, E. ... 55
Lucas, D. H. ... 157

Maczewski-Rowinski, B. ... 160
Marsh, A. ... 42
Martine, W. R. ... 245, 265
McConnell, S. G. ... 115
Meade, P. J. ... 207
Moulds, W. ... 189
Müller, T. ... 44

Newton, D. L. ... 259
Nonhebel, G. ... 250, 270
Nose, Y. ... 209, 268

Paccagnella, B. ... 167
Paleari, C. ... 106
Parker, A. ... 257, 265
Pelletier, J. ... 122, 261
Petrilli, F. L. ... 172, 212
Pixova, J. ... 181
Polacek, J. ... 45
Polydorova, M. ... 181
Powell, L. H. ... 275

Queret, Y. ... 47

Randall, W. ... 117
Ratzki, E. ... 177
Redfearn, M. W. ... 130
Redstone, F. J. ... 264
Reif, A. E. ... 214, 268
Renzanigo, F. ... 106
Renzetti, N. A. ... 216
Riasanov, V. A. ... 175
Riello, P. ... 110
Ronge, H. ... 20

Schmidt, O. ... 48
Schreibeis, Lee J. ... 50
Schwarz, K. ... 177

Page

Scorer, R. S. ... 228
Seidl, W. ... 200
Semple. A. B. ... 243
Spaak, R. ... 20
Spurny, K. ... 55, 181
Spurr, G. ... 234
Stansbury, C. A. ... 257
Stern, A. C. ... 201, 253, 263
Sutton, Sir Graham ... 15

Tesch, J. W. ... 267, 277
Tetzlaff, F. ... 58
Thieme, Dipl. Ing. ... 206
Thring, M. W. ... 115
Truffert, L. ... 260

Page

Turner, T. Henry ... 259
Turner, W. C. ... 251, 265

Underwood, G. ... 115

Waller, R. E. ... 236
Watson, D. ... 115
Watson, C. A. ... 245, 253
Wattleworth, W. H. ... 246
Weinberg, S. ... 117
Wightman, Mrs. A. P. ... 253
Wilkins, E. T. ... 256, 271
Wilson, D. S. ... 258, 266
Wolf, E. F. ... 239

SUBJECT INDEX

Note: A.P. means Air Pollution

Acidic smuts; Elimination of, 99.

Additives; for Diesel oil, 106.

Administration; Great Britain, 18; St. Louis, U.S. 21; Ireland, 23; Canada, 34; Czechoslovakia, 45; Allegheny County, U.S., 50; United States, 58, 276; of Environmental Arsenic in Smelting, 86; Cheaper Cleaning Equipment, 91; International Problems in Relation to, 120; Steps taken in Federal Germany by Local Authorities, 204.

Air cleaning equipment; Cheaper, 91.

Alkali inspectors; Criticisms of Report of, 245; Reply to Criticisms, 248; Numbers, 275; Regional Alternative, 278.

Arsenic; Environmental Contamination in Smelting, 86.

Ash; see Dust, Grit and Ash.

Associations, see Organizations.

Belgium; Activities in, 38; Commended Solution of Problems, 74.

Bronchitis; Mortality and Morbidity from in Sheffield, 189, 267; Predisposition, A.P., and, 268; Reply by Dr. Clifton to Discussion, 269.

Canada; Control in, 34; Environmental Arsenic Contamination, 86; Standardization of Methods of Sampling and Analysis, 147.

Cancer; Causation by Pollutants, 214; by Tobacco, 268.

Carbon monoxide; Effects of Additives on, in Diesel Oil, 106.

Chimneys; Possible Permitted Maximum Dust Loading, 246; Penetration of Inversions, 234, 265; Design of, 267.

Coal; and Modern Equipment, 117; Smoke Emission from Coal-Fired Single Stoves, 206; Miners' Concessionary, 248; Use of, 251.

Coking industry, 72.

Combustion; Essential Condition for Perfect, 110; Smoke from Low-Temperature Furnaces, 115; Coal and Modern Equipment, 117.

Concentrations; Calculations of from Domestic Sources, 157; Maximum Allowable in U.S.S.R., 175.

Control; see Administration.

Co-operation; in Research in Europe, Extent and Possibilities, 185; in International Documentation, 200; International, in Research, 203.

Czechoslovakia; Clean Air and Means for Improvement, 45; Problems, 55; Determination of Particle Sizes, 181.

Diesel road vehicles; Problems of, 85; Effects of Additives, 106; Amendment of Legislation on, 245; Reply to Suggested Amendments, 249; Testing of, 254; Sealing Oil Pumps of, 260.

Dust, grit and ash; Fly-Ash Collection, 63; from Steelworks, 79; as Dealt with by European Coal and Steel Community, 82; Dust and Gaseous Moisture, 93; Monitoring Surface Area, 135; Measurement to Determine Sources of Damage to Crops, 154; Abatement by Means of a Siren, 160; Use of Scale Models in Design of Collector Systems, 239; Measurement, 258; Relative Hazards of Different Sizes, 261.

Economy; Coal and Modern Equipment in Relation to, 117.

Education; in Japan, 31; in United Kingdom, 42; as an Aid to Industrial Smoke Elimination, 76, 275; of Public, 266; in Schools, 266.

Effects; of A.P. on Community Health, 209; on Health, of Various Sizes of Dust, 135; on Bronchitis and Pneumonia, 268.

Electrostatic precipitators; in Steelworks, 79; for Assessment of Domestic Smoke, 194.

Europe; Coal and Steel Community, 82; Co-operative Research, Extent and Possibilities, 185.

France; Problems of Dust and Gaseous Moisture at Emission Points, 93; Pollution in Paris Area, 122.

Fuel; Growth in World Consumption, 60; Second-Rate, 63.

Gas; in Industry, 83.

Germany, Federal Republic; Measurement and Laws, 25; Problems, 27; Parliamentary Initiative in, 48; Removal of Dust from Steelworks, 79; Cheaper Cleaning Equipment, 91; International Problems, 120; Contributions to Smog Problem, 139; Standardized Methods in Surveys, 153; Dust to Crops, 154; Research in Essen, 177; International Co-operation in Documentation, 200; Measurements to Determine Sources of Damage Steps taken by Local Authorities in, 204; Smoke from Coal-Fired Stoves, 206.

Great britain; Administration, 18; Legislation, 18; Public Opinion and Education, 42; Smokeless Fuels, 66; Coking Industry, 72; Gas in Industry, 83; Problem of Diesel Road Vehicles, 85; Sulphur, 102; Smoke Emission, 115; Coal, Modern Equipment and Clean Air, 117; Sulphur Dioxide near Power Stations, 130; Monitoring Dust Surface Area, 135; Sulphur and Smoke from Domestic Appliances, 197; Inversions, 207; Photography, 228; Penetration of Inversions by Hot Plumes, 234; Air Pollution in City of London, 236.

Grit, see Dust, Grit and Ash.

Health; Effects of Exposure to A.P., on, 209; Relations between A.P. and Public Health, 212; Carcinogenesis by Pollutants, 214; Effects of Various Sizes of Dust, 135; Bronchitis, 267; Effects of A.P. on Bronchitis, 268.

Hydrocarbons; Photochemical Aerosol Formation in SO_2-Hydrocarbon Systems, 216.

Incinerators; Flue Fed, 247, 270; for Burning Motor Car Bodies, 247, 275.

Industry; Gas in, 83.

International; Problems, 120; Co-operation in Documentation, 200; Co-operation in Research, 203; Co-operation, General, 263, 269, 271.

Introduction; 14.

Inversions; and A.P., 207; Penetration of, by Hot Plumes, 234, 265, 276.

Ireland; 23.

Italy; Effects of Diesel Oil, Additives, 106; Essential Condition for Perfect Combustion, 110; Researches in Milan, 133; Investigations in Padua, 167; Pollution in Genoa, 172; Relations between A.P. and Public Health, 212.

Japan; Public Opinion and Education in, 31; Legislation, 32; Research and Investigation, 142; Effects on Community Health, 209.

LEGISLATION; Great Britain, 18; Ireland, 23; West Germany, 25; Japan, 32; United States, 58; Poland, 266.

MEASUREMENT; Sweden, 20; West Germany, 25; Switzerland, 44; Czechoslovakia, 45; International Problems of Inspection and Assessment, 120; Paris Area, 122; of Sulphur Dioxide near Power Stations, 130; Milan, 133; of Dust Surface Area, 135; Standardization of Sampling Analysis, 147; Standardization in Surveys, 153; of Dust to Determine Sources of Crop Damage, 154; Sulphur and Smoke from Domestic Sources, 157; in Padua, 167; in Genoa, 172; in Essen, 177; of Particle Sizes, 181; Electro-Precipitation for the Assessment of Domestic Smoke, 194; in City of London, 236; Discussion, 257.
MORTALITY AND MORBIDITY; from Bronchitis in Sheffield, 189.

NITROGEN OXIDES; Effects of Additives on, in Diesel Oil, 106.
NORWAY; Problems, 40.

OIL-FIRING; Acid Smuts from, 99, 255, 257; Essential Conditions for Perfect Combustion in, 110; in Paris, 259; Solids and Sulphur from, 277.
ORGANIZATIONS; French Association, 47; European Coal and Steel Community, 82.

PHOTOCHEMICAL; Aerosol Formation in SO_2-Hydrocarbon Systems, 216.
PHOTOGRAPHY; of A.P., 228.
PLANTS; Damage to Crops, Dust Measurements to Determine Source, 154; Research on Damage to Vegetation at University of California, 193.
POLAND; Dust Abatement by Means of a Siren, 160; Legislation, 266.
PROBLEMS; West Germany, 27; Norway, 40; Czechoslovakia, 55; of Coking Industry, 72; Commended Solution, 74; of Diesel Road Vehicles, 85; of Dust and Gaseous Moisture, 93; International, 120; of Smog, Contributions to, 139; of Smoke Emission from Coal-Fired Stoves, 206.
PUBLIC OPINION; in South Africa, 29; in Japan, 31; United Kingdom, 42, 275.

RESEARCH; in Milan, 133; in South Africa, 137; and Investigation in Japan, 142; in Essen, 177; Cooperative in Europe, Extent and Possibilities, 185; on Damage to Vegetation, 193; Current Status of in U.S.A., 201.

SCALE MODELS; Use in Design of Dust Collector and Gas Duct Systems, 239.
SMOKE CONTROL AREAS; Need to Streamline Procedure, 247; Reply to Suggested Need to Streamline Procedure, 249.
SMOKE ELIMINATION; Education as an Aid to Industrial, 76.
SMOKE EMISSION; from Low-Temperature Furnaces, 115; Calculation of Concentration from Domestic Sources, 157; from Domestic Appliances, 197; from Coal-Fired Single Stoves, 206.
SMOKELESS FUELS; Development of, 66; Demand for, 252, 270; in South Wales, 275.
SOCIETIES; see Organizations.
SOUTH AFRICA; Public Opinion, 29; Research in, 137; Durban Campaign, 143.
STANDARDIZATION; of Sampling and Analysis, 147; in Surveys, 153; of Measurements, 259, 261, 271.
STEELWORKS; Removal of Dust from Oxygen-Blowing, 79.
SULPHUR; in the Air, 102; Dioxide near Power Stations, 130; Calculation of Concentration from Domestic Sources, 157; from Domestic Appliances, 187, 266; Photochemical Aerosol Formation in SO_2- Hydrocarbon Systems, 216; Removal from Petroleum, 252; Recovery, 253; Removal from Oil in U.S.A., 253; in Colliery Refuse, 255; Measurement, 258; in Fuel Oil, 261, 271; Reply by L. W. Andrew to Discussion on his Paper, 268; Emission from Oil-Firing, 277.
SWEDEN; Measurement, 20.
SWITZERLAND; Measurement of A.P. in Basle, 44.

U.S.S.R.; Maximum Allowable Concentrations of Pollutants in, 175.
U.S.A.; St. Louis, 21; Allegheny County, 50; Legislation and Administration, 58; Research on Damage to Vegetation, 193; Current Status of Research in, 201; Carcinogenesis by Pollutants, 214; Photochemical Aerosol Formation in SO_2-Hydrocarbon Systems, 216; Use of Transparent Scale Models in Design of Dust Collector and Gas Duct Systems, 239.

VEHICLES; for Diesel, see Diesel Road Vehicles; Sulphur from, 254.

Index to Advertisers.

	Page
Air Control Installations Ltd.	1
Boston Marine & General Engineering Co. Ltd.	290
British Coking Industry Association	273
Filter Heat Ltd.	2
Gas Council Film Library	4
G.W.B. Furnaces Ltd.	7
Harris Engineering Co. Ltd.	285
Holmes, W. C. & Co. Ltd.	274
Lancashire Dynamo Electronic Products Ltd.	10
Lodge Cottrell Ltd.	286
National Carbonizing Co. Ltd.	287
National Coal Board	3
Sayvoil Co. Ltd.	288
Shell Mex & B.P. Ltd.	5
Simon Carves Ltd.	6
Solid Smokeless Fuels Federation	289

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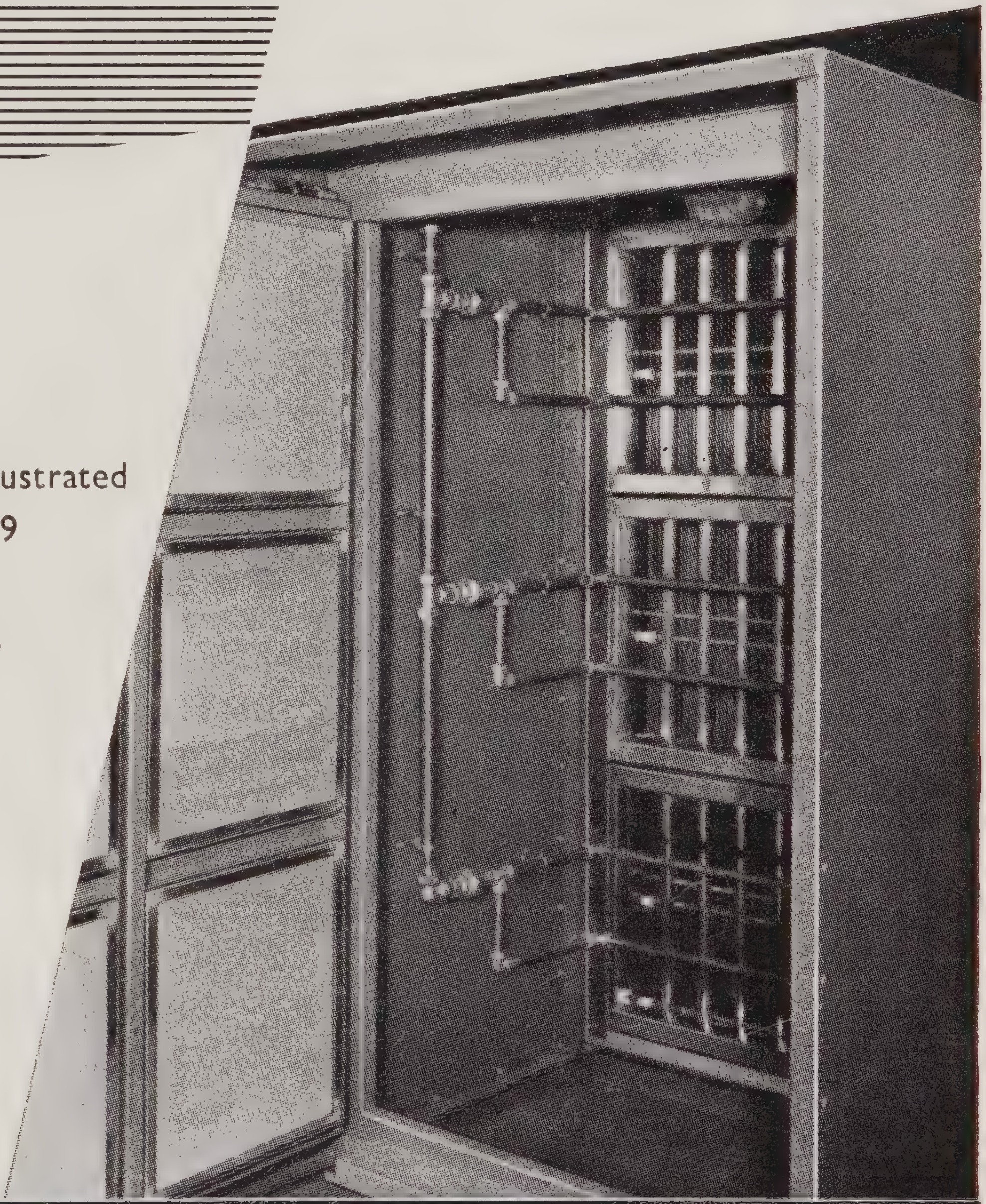

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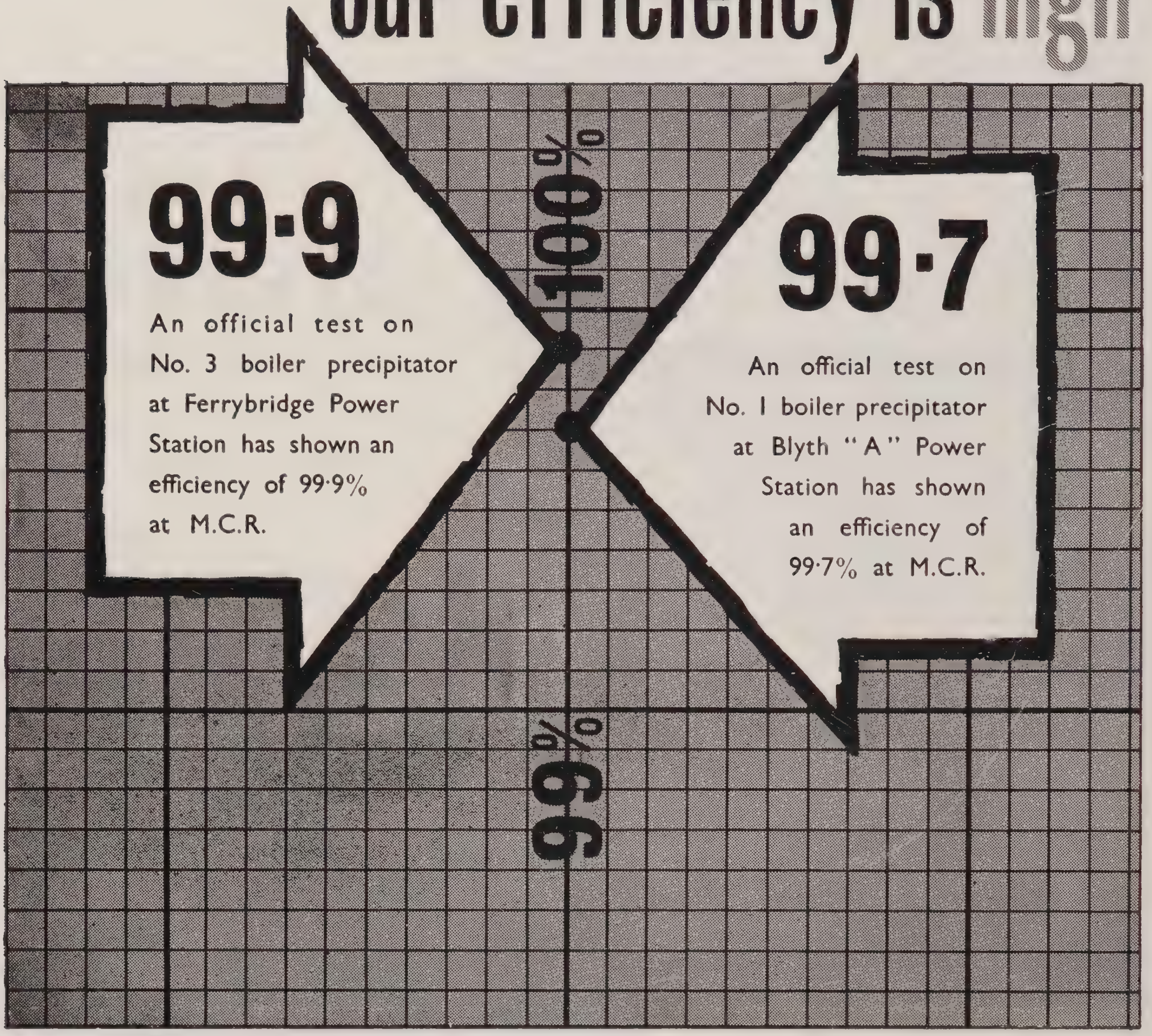

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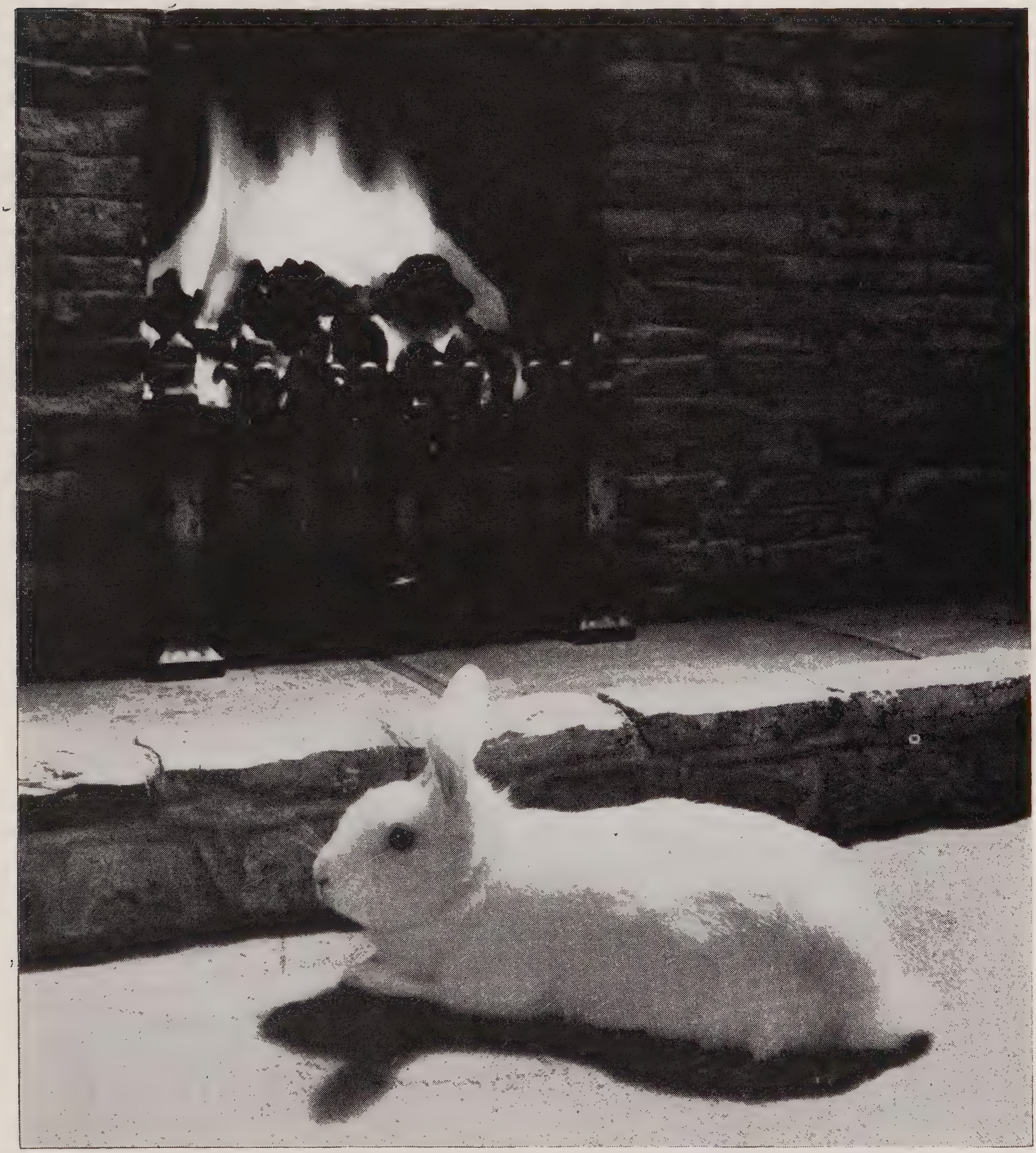

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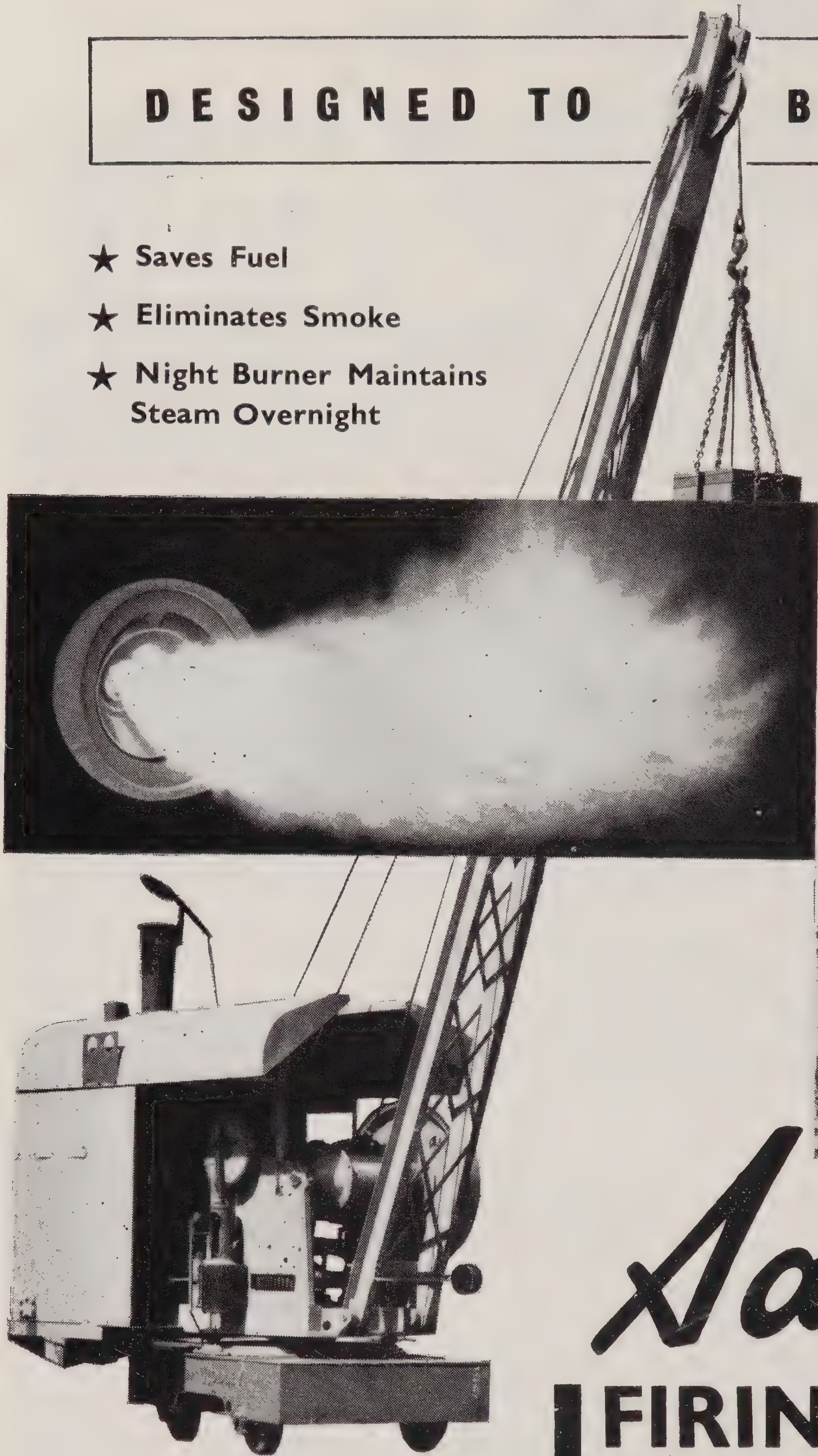

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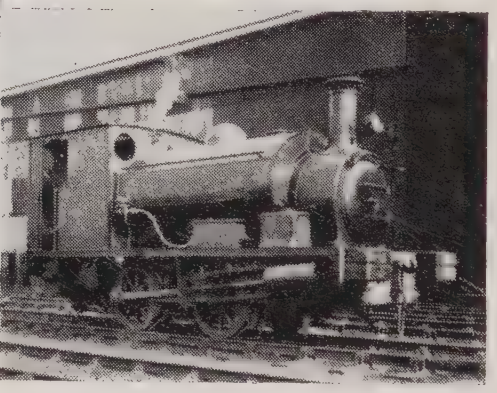

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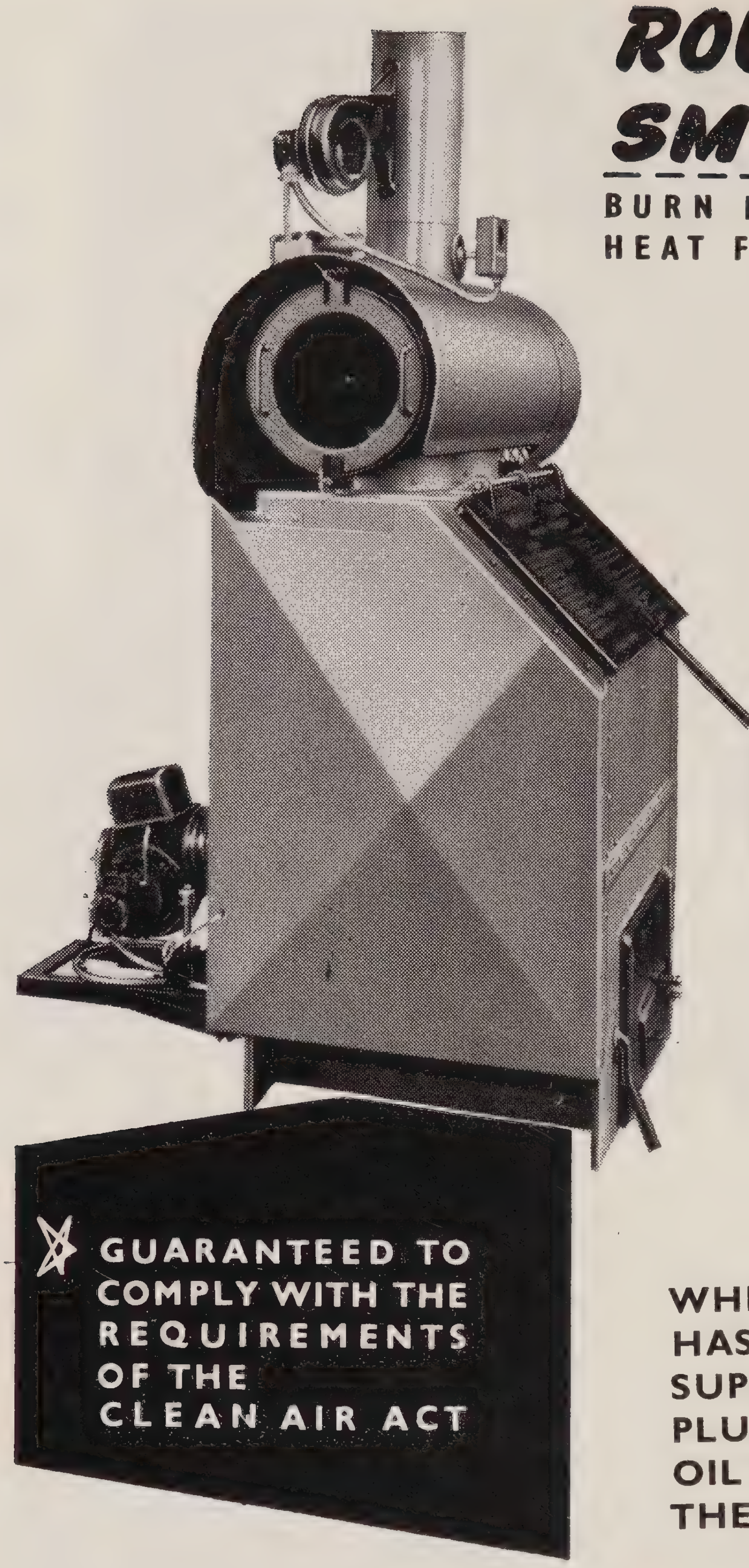

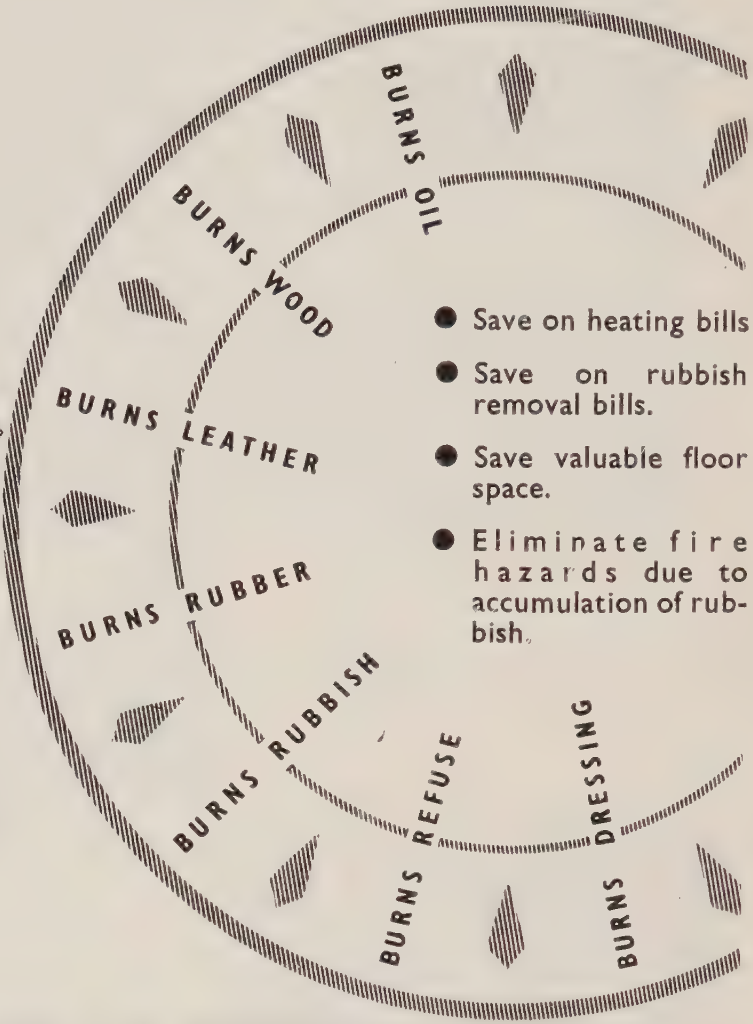

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20th-23rd October, 1959

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Page

Alphabetical List of Members and Delegates 2

List of Local Authorities Represented and Delegates Appointed 15

List of Associations, etc., Represented and Delegates Appointed 25

List of Overseas Countries Represented and Delegates Appointed 29

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SIXTY YEARS
FOR
CLEAN AIR

DIAMOND JUBILEE
CONFERENCE & EXHIBITION

NATIONAL SOCIETY FOR CLEAN AIR

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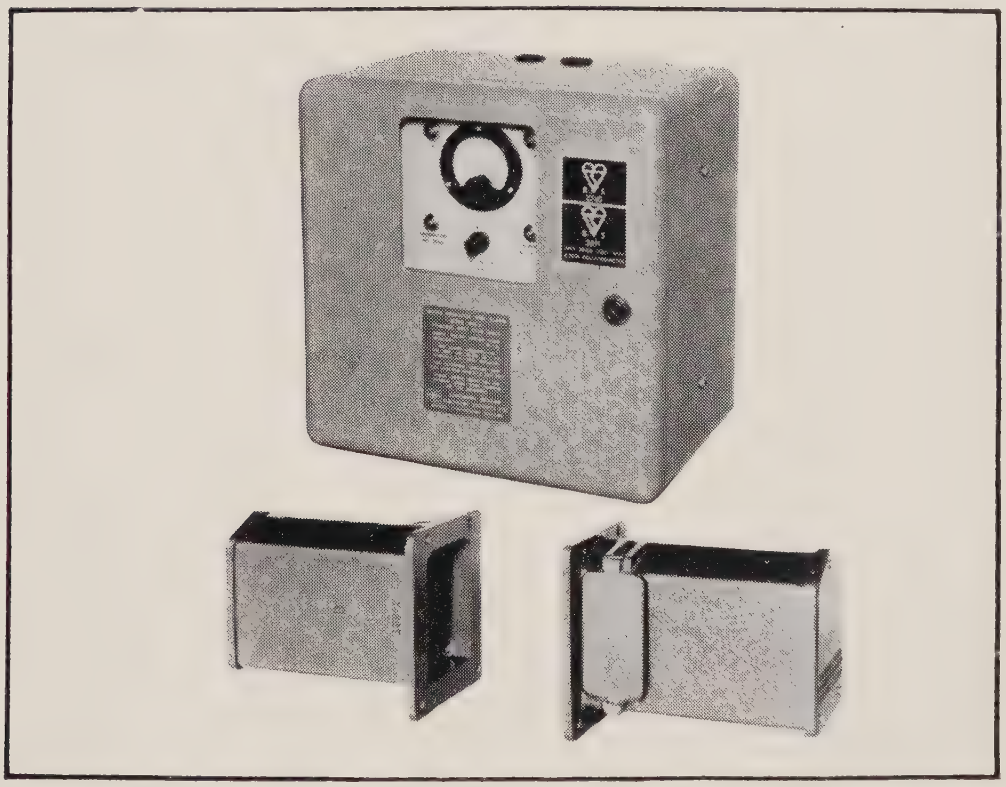

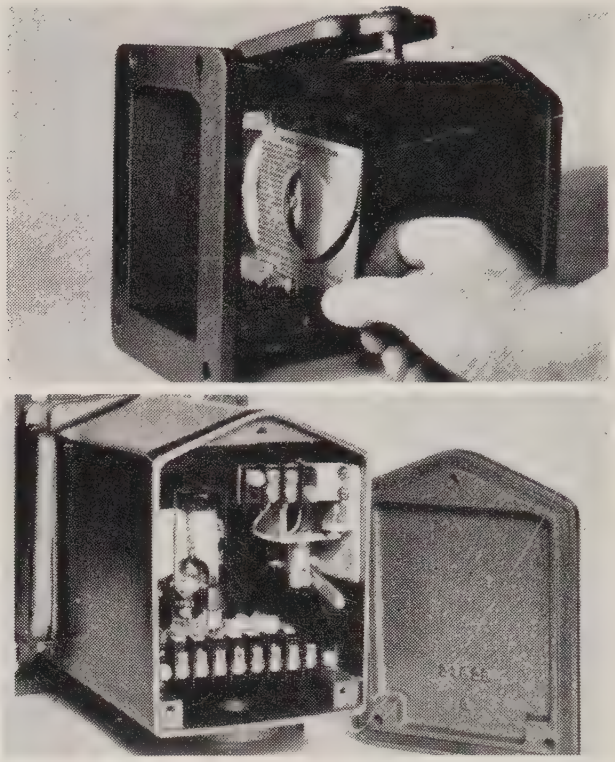

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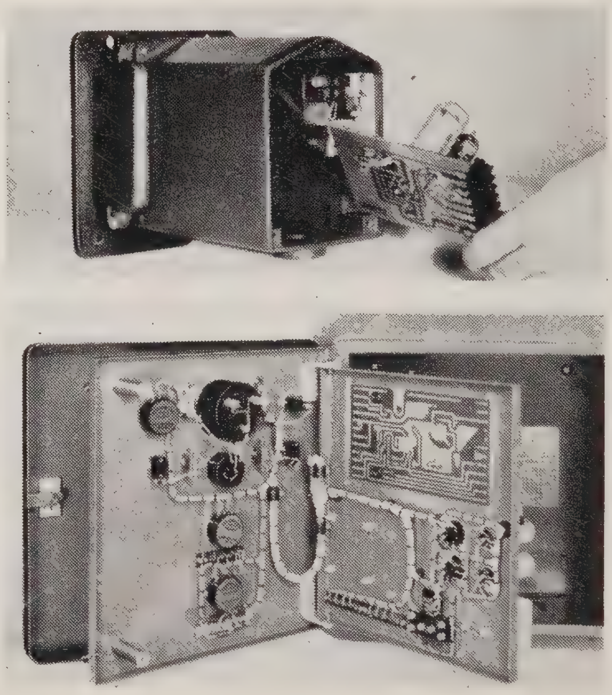

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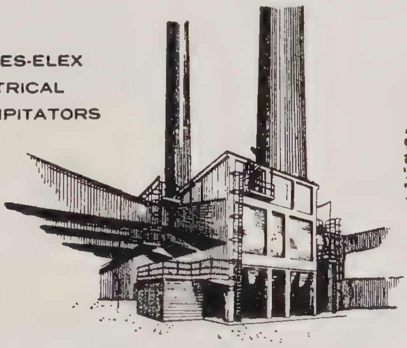
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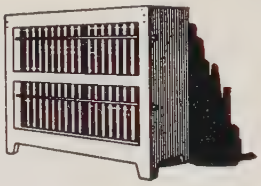
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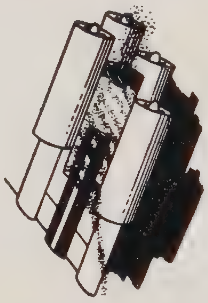
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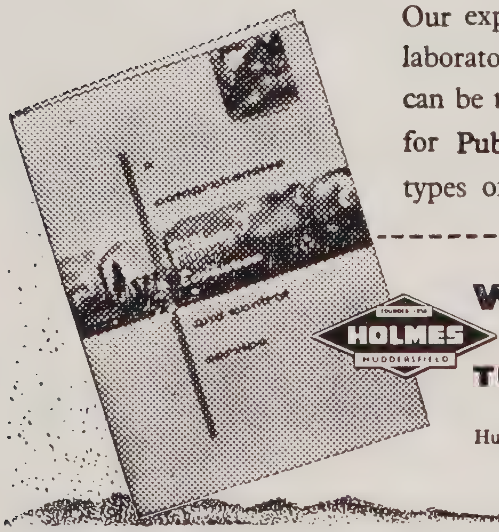

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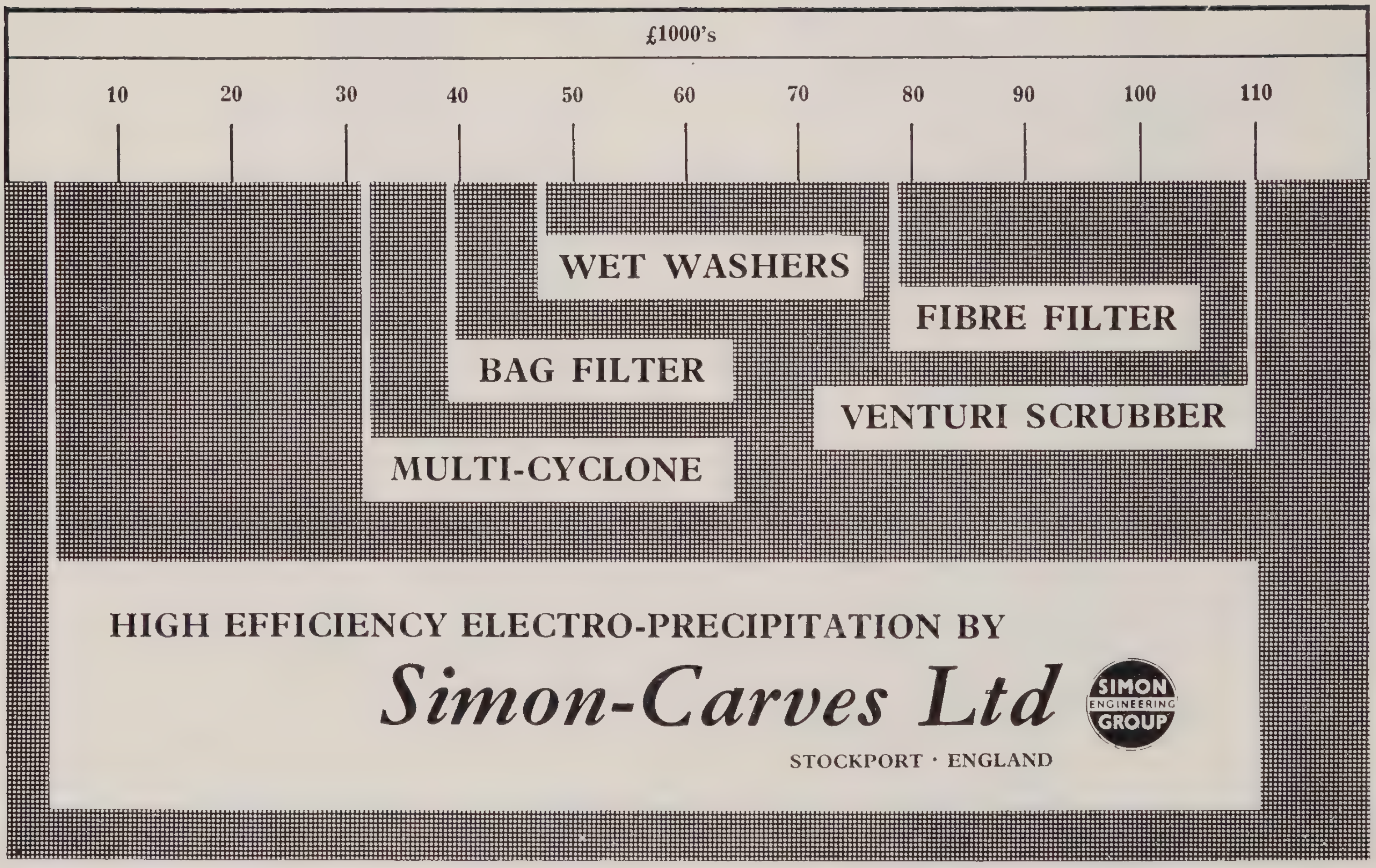

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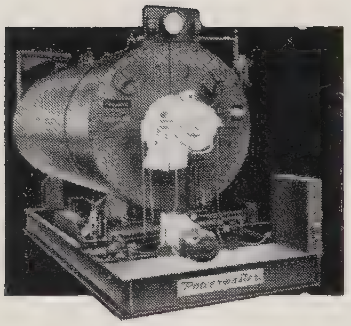

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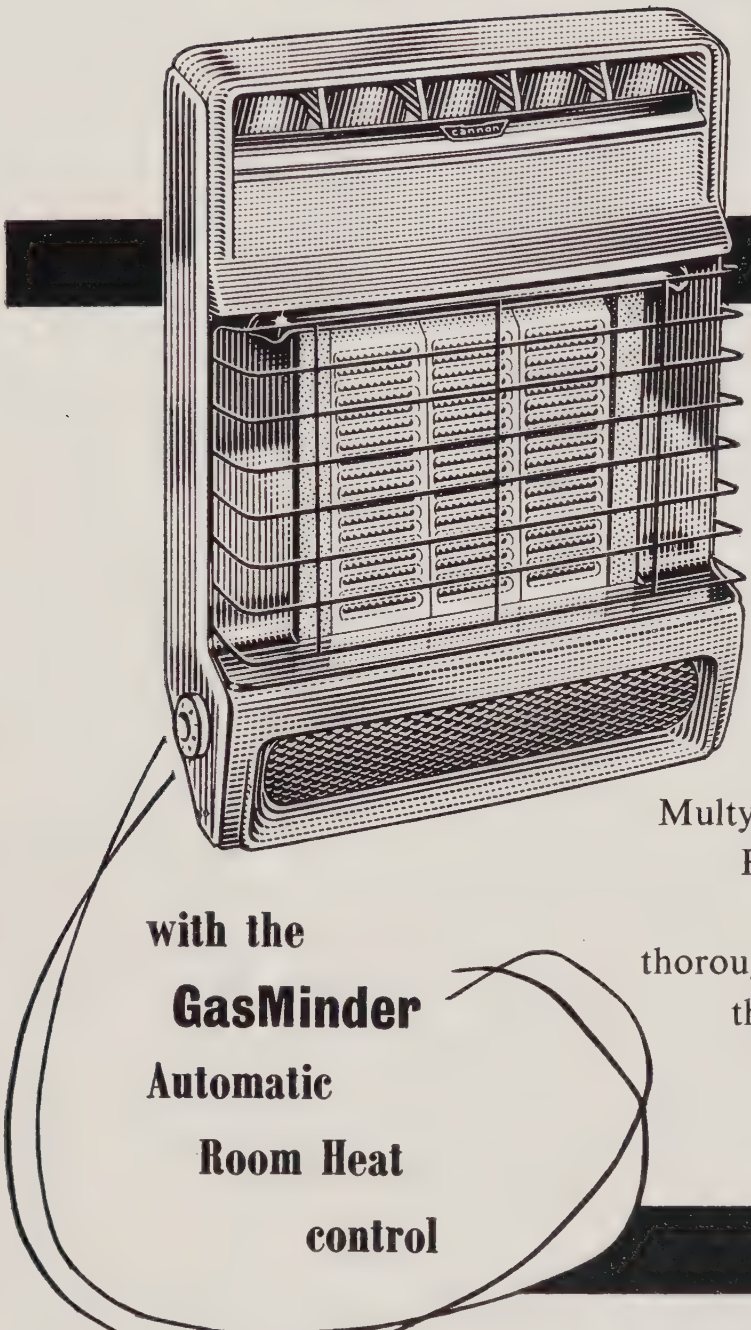

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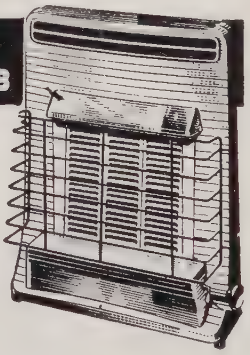

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SIXTY YEARS FOR CLEAN AIR

Handbook for the Diamond Jubilee International Conference and Exhibition

Patron : H.R.H. The Duke of Edinburgh, K.T., K.G.

Seymour Hall, Seymour Place, London, W.1
20th to 23rd October, 1959

CONTENTS

H.R.H. the Duke of Edinburgh, Patron 10
Foreword by the President, Sir Hugh Beaver 11
The Story of the Society 12
Past and Present Officers, etc. 20
How to Reach Seymour Hall 21
The Rt. Hon. the Lord Mayor of London, Sir Harold Gillett 22
To Open the Sessions 23
The Mayor of St Marylebone and Sessional Chairmen 24
Conference Information 25
Plan of Seymour Hall 29
CONFERENCE PROGRAMME 30
GUIDE TO THE EXHIBITION 35

INDEX TO EXHIBITORS AND ADVERTISERS

	Stand Description	*Advertisement*
Airflow Developments Ltd. ..	—	Cover iii
British Iron and Steel Federation	35	34
British Transport Commission	35	—
Cannon (GA) Ltd.	—	8
Central Electricity Generating Board	35	49
Chemical Construction (G.B.) Ltd.	37	—
Coal Utilization Council ..	37	—
Coalite and Chemical Products Ltd.	38	39
College of Fuel Technology ..	39	—
Combustion Equipment Ltd.	—	26
Danks Ltd., Edwin	40	41
District Bank Ltd.	40	5
Drummond Patents Ltd. ..	40	—
Dunedin Engineering Co. Ltd.	40	—
Electrical Development Association	43	42
Gas Council	43	Cover iv
General Electric Company ..	44	—
Gordon & Co. Ltd., James ..	44	—
G.W.B. Furnaces Ltd. ..	—	6 & 7
Holmes & Co. Ltd., W. C. ..	44	1
Ideal Boilers and Radiators Ltd.	—	28
Lancashire Dynamo Electronic Products Ltd.	45	Cover ii
Lodge Cottrell Ltd.	45	—
Ministry of Housing and Local Government	47	—
Mirlees Watson Co. Ltd. ..	47	—
National Carbonizing Co. Ltd.	47	4
National Coal Board	—	55
National Industrial Fuel Efficiency Service	47	46
National Society for Clean Air	48	21
Potterton Ltd., Thomas ..	—	56
Prat-Daniels (Stroud) Ltd. ..	48	—
Shell-Mex & B.P. Ltd. ..	48	—
Simon Carves Ltd.	48	2 & 3
Smoke Burners Ltd.	—	27
Solid Smokeless Fuels Federation	50	54
Sturtevant Engineering Co. Ltd.	50	51
Troup Ltd., John D.	52	—
Warren Spring Laboratory, D.S.I.R.	52	—
Women's Advisory Council on Solid Fuel	52	—

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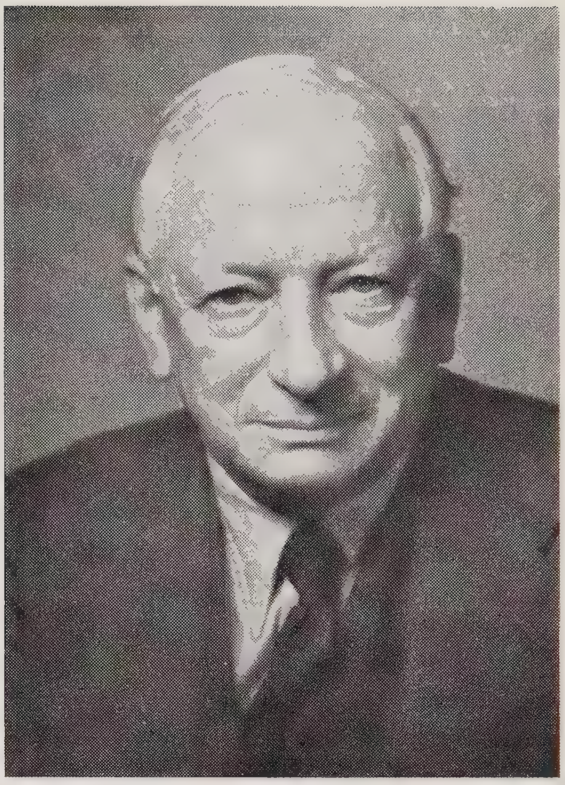
Patron to the Conference and Exhibition

Foreword

By the President,

Sir Hugh Beaver, K.B.E.



THE programme of the Society's International Clean Air Conference included in this Handbook shows very clearly the world-wide concern that prevails today about air pollution, while the Guide to the Exhibition illustrates the extent to which science and technology are contributing to the elucidation and solution of these problems. To bring together such a comprehensive conference and exhibition, through which we can both assess our present situation and look forward into the future, is ample justification for the celebration by the Society of its Diamond Jubilee, but it is equally justifiable on such an occasion for the Society to look back, not without pride, over its sixty years of effort and to pay tribute to those who made it all possible.

Perhaps the most remarkable thing about this Diamond Jubilee is that a Society concerned exclusively with a problem that until recently has been of very restricted public interest, and which has always had to work with very limited support, should have kept itself in active being for so long a time. How it has carried on and made progress against all kinds of difficulty can be discerned from the brief history that is given in the following pages—it has been mainly because of the enthusiasm and determination of a quite small number of individuals. In acknowledging their services and recording some of the achievements the Society has to its credit we can underline and emphasize the work still to be done, assured as it now is of wider support both in our own and in many other countries, whose representatives we welcome here with appreciation and friendship.

THE SOCIETY'S STORY

How the Society Began

THE National Society for Clean Air can celebrate its Diamond Jubilee this year because, despite changes of name and an amalgamation, there is a lineal and unbroken descent from the Coal Smoke Abatement Society that was formed in London in 1899. The records we possess are not complete, and there had been some doubt as to whether 1898 or 1899 was the actual year of birth. The facts are that the Society was conceived in December 1898, when a meeting was held and decided to establish a Society, and that in 1899 another meeting took place at which the Society was formally brought into being with the name it bore so honourably for the next thirty years.

It is a pity that our records of those early days are not as full as they might be, and it would be particularly interesting to know the story of the precursor of the Society, the National Smoke Abatement Institution, formed as early as 1881 at a meeting in the Mansion House, which appears to have been attended very largely by titled people. (It is a sign of the way in which times have changed to note how all these early activities for clean air were strongly supported or patronized by members of the peerage.) This meeting came about as the result of an exhibition held in South Kensington by the Kyrle Society and the National Health Society, which drew an attendance of 116,000, and engendered much enthusiasm for smoke abatement. This must, however, have been short-lived, for after a few years the Institution seems to have faded quietly away.

In 1891 a Public Health (London) Act was passed, containing smoke nuisance provisions similar to those included for the rest of the country in the Public Health Act of 1875. It was the neglect of these powers that finally brought together the people who, at a meeting held at 6 Onslow Gardens, S.W.1, on 6th December 1898, decided to set up a Society. The Earl of Meath was in the Chair, and the main address was given by Sir William Richmond, a Royal Academician, whom the Earl described as their new leader. Sir William's speech, of which one press report survives, made it clear why the Society was being formed. There was an Act of Parliament to control industrial smoke, but (although the London County Council had done a little), it was largely a dead-letter because the evidence in any case had to be submitted to the court by the Vestries—the forerunners of the Borough Councils—which were apparently quite uninterested and would make no effort to obtain evidence with which to institute prosecutions. The main object of the Society, it seems, was to obtain the evidence, present it to the Vestries, and then prod them to make use of it. If this could be done, then Sir William was satisfied that "so far as smoke from factories is concerned, in a

Sir William Richmond, R.A.

President of the Coal Smoke Abatement Society from its formation in 1899 very short time London will be rid of their contribution to a very serious if not dangerous nuisance, and one that at the present time is growing with monstrous rapidity."

Sir William read two messages he had received, one from the niece of the aged and infirm John Ruskin—whom he called "that blessed leader in all things beautiful"—which read: "I have to congratulate you from Mr. Ruskin for fighting this battle against the villain, smoke."

The other was from Sir John Brunner, one of the great industrialists of his age, who stated a truth that the new Society was to spend many years in driving home:

> "My experiences as a manufacturer proves to me that the evolution of black smoke can be stopped with profit, simply by taking care to burn the coal scientifically. For the rest, I congratulate you on having initiated this movement . . . "

The resolution, which was unanimously carried by the meeting, was moved by Sir William Richmond and seconded by Lady Frederick Cavendish, and read as follows:

> "That a Society be formed, and a Committee appointed, to consider and report how best Vestries and other Municipal Bodies can be aided by Public support to enforce the clauses in the Public Health Acts which relate to Smoke Consumption."

The Committee met for the first time on 10th January 1899, and it is fitting that the names of its members should be recorded in this Sixtieth Anniversary tribute. They were: The Duke of Westminster, Lord Ashcombe, Professor Thorpe, F.R.S., Viscount Midleton, Sir Arthur Wells, Owen Thomas, Sir Charles Cookson, Professor Mendola, F.R.S., The Hon. Rollo Russell, Thackeray Turner, Surgeon Lieut.-Col. Cazey, The Lord Robert Cecil, Lord Dunraven, The Rt. Hon. G. J. Shaw Lefevre, Dr. W. J. Collins, The Earl of Meath, H. T. Boodle, T. F. Cornish, Lord Kelvin, Lord Welby, Sir William Richmond, Sir William Priestley, Sir Henry Thompson, Frederick W. Verney and Dr. H. A. Des Vœux.

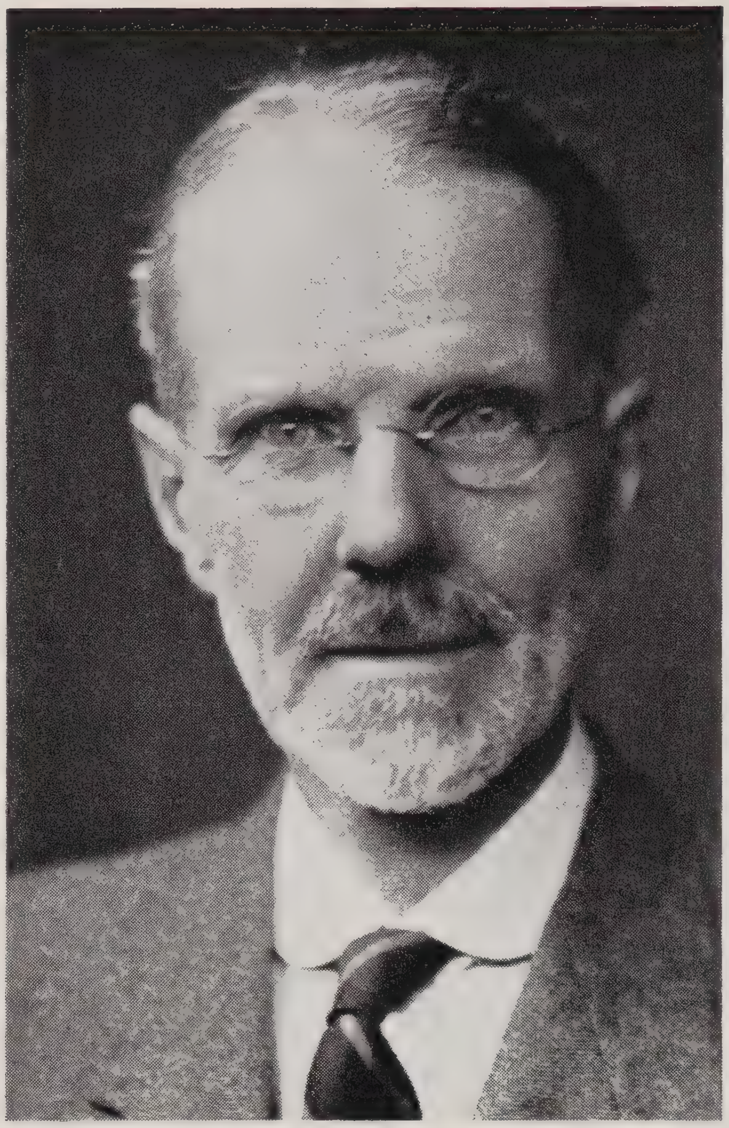
The last named, Dr. Des Vœux, was perhaps even then the mainspring of the movement, and when a meeting in 1899 formally established the new body under the name of Coal Smoke Abatement Society he was elected as Hon. Treasurer, with Sir William Richmond as President.

The Early Years

During the next decade or so, led by its determined office-bearers and undeterred by the fact that the annual income seems never to have exceeded about £300, the young Society made striking progress. After a year or two, it was fortunate in securing the services, as a paid but part-time Secretary, of Lawrence Chubb. With Des Vœux he was to lead and influence the smoke abatement movement for many years, even though an increasing part of his time was to be occupied with other work. He was the first secretary to the National Trust, secretary to the Commons and Footpaths Preservation Society and, much later, to the National Playing Fields Association. Deservedly rewarded by a Knighthood in 1930, he maintained his connection with the Society as Hon. Advisory Secretary and then as Hon. Treasurer, almost until his death in 1948.

The new Society seems to have achieved a good reputation for itself quite quickly, and by 1902 we find a leading article in *The Lancet* saying:

> "The Coal Smoke Abatement Society is a most useful institution which has not received anything like the attention which it deserves. Especially would we urge upon medical men that the work upon which this society is engaged is worthy of their support, for the part that is played in pathology by the murky atmosphere of London and other of our great cities can hardly be exaggerated. The Society needs subscribers and its justification in asking for them lies in its published work. A glance at the balance sheet of the Society, issued with the last annual report, shows that the small sum which has been placed by the public at the disposal of the executive has been most judiciously used. Unlike many other somewhat similar societies nothing has been wasted in the multiplication of direct or indirect advertisements, but the money has been spent in actual and valuable work, often of an arduous and delicate nature."



Dr. Harold A. Des Vœux

Hon. Treasurer, Coal Smoke Abatement Society, 1899-1929, *President, National Smoke Abatement Society,* 1929-1942

The Lancet itself notably assisted the Society by publishing in 1902, 1904 and 1906, the reports of the first important investigation undertaken by the Society—testing of domestic grates to determine their efficiencies and the degree to which smoke emission could be reduced. This work was carried out by Dr. Des Vœux and Mr. Bryan Donkin, and had the co-operation of the Royal Institute of British Architects and the Office of Works—the work was carried out in rooms in the new Government offices which are now the Ministry of Housing and Local Government. A considerable number of grates were tested, some showing that they produced much less smoke than others, but the hope of finding an open grate that would burn bituminous coal without smoke was never realized.

The routine work of the Society was, however, to press for the law to be administered, and funds just made possible the employment of an Inspector of its own, a Mr. William Petty. In the year 1903 he reported 2,000 observations which had led to 1,278 complaints being forwarded to the local authorities. "Following these complaints", says the report, "40 summonses were issued under the Acts, involving the offending firms in penalties and costs to the amount of £104 15s." The report was able to refer to the harmonious relations which then existed with many authorities—some of which were now beginning to appoint their own Inspectors. In some cases observations were made by the Police (in Nottingham by the Police only), and in one town a policeman always accompanied an inspector in making observations. But as an example of the kind of work which still lay before the Society was mentioned the case of one authority in East London to which 572 complaints had been addressed without a single case being brought to court—although in two cases the nuisance was so scandalous that an adjoining borough had issued summonses on the report of its own officers and had obtained convictions.

By 1905 the Society was able to hold, jointly with the Royal Sanitary Institute, a four-day smoke abatement conference and exhibition, under the presidency of another distinguished person, Sir Oliver Lodge. This was attended by representatives of some forty local authorities, a number of professional institutions and four universities.

In 1906 another important investigation was carried out by the Society on gas stoves, "relating to their thermal efficiency and to hygienic consideration." These tests, conducted by Dr. Des Vœux and Dr. John S. Owens, not only indicated the relative efficiencies of different types of gas fire, but exploded the fallacies then prevalent (and even today not entirely dead) that gas heating "vitiated" the air of the room or increased its carbon monoxide or carbon dioxide content. They also enabled some useful suggestion to be made for improvements in gas fire design. Once again the report was published in *The Lancet* (17th November 1906).

In January to April 1907 the Society inaugurated a movement which it has fostered and encouraged ever since—the training of boiler operators or stokers. As far as we know the first series of lectures ever to be held for this purpose were given under the auspices of the Society in that year at the Borough Polytechnic by W. H. Booth.

An interesting and far-reaching development in the early part of 1910, when Dr. Des

Vœux and Dr. Owens approached the Commissioners of the *Lancet* laboratory "in regard to making some experiments in the direction of estimating the matters deposited from London atmosphere at regular intervals over a period of a year at various stations in the metropolitan area." A scheme was eventually formulated and the first serious observations began in June 1910. A gauge was constructed for catching the deposit which is in all essentials exactly the same as the deposit gauge used today. Three sites were chosen in central London and one, for comparison, in Sutton, Surrey. The deposits were analyzed for soluble and insoluble matter, sulphates, ammonia, chlorides and lime, again very similar to present day practice. The total deposits for this first year of observations in tons per square mile are worth noting:

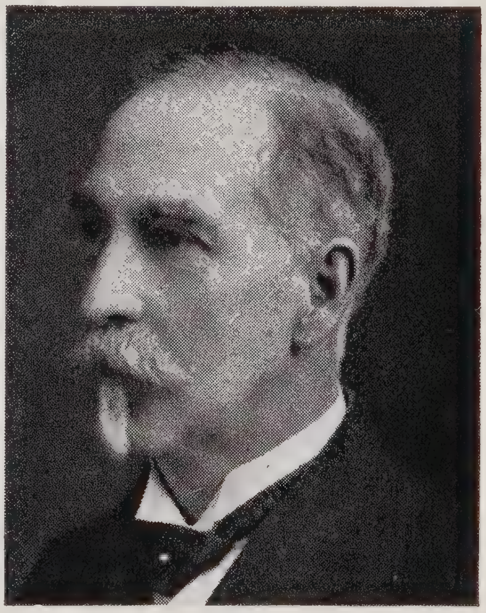
Buckingham Gate, S.W.1...	500
Horseferry Road, S.W.1. ..	420
Old Street, E.C.	650
Sutton, Surrey	195

The analyses were carried out in *The Lancet's* laboratories, and the detailed report was published in the journal on 6th January 1912. From this small beginning the observations were continued and expanded, and the work was later passed over to the Meteorological Office, which continued to supervise and collate the records until 1926, when the Advisory Committee that had been set up became the Standing Conference of Co-operating Bodies, and the Department of Scientific and Industrial Research became responsible for the Government's side of the work.

In 1912 the Society organized an International Smoke Abatement Exhibition in the Agricultural Hall, London, an account of which has recently been published in *Smokeless Air* (Summer, 1959). In conjunction with the Exhibition a three-day conference was held, attended by about 150 delegates from some sixty local authorities, forty from various association, and sixteen from overseas—Holland, Germany, Sweden and the United States. The Hon. Secretary for the Conference was our Immediate Past President, Dr. R. Lessing, C.B.E. A considerable number of papers was read and discussed, but the main interest of the conference to us today lies in the resolutions that were adopted calling for support for a Smoke Abatement Bill (drafted by the Smoke Abatement League in Manchester) to be introduced into the House of Commons, and for a Royal Commission to investigate the problem. From these resolutions came the activities that led to the setting up of the Newton Committee on Smoke and Noxious Vapours Abatement, and eventually—after the serious set back caused by the 1914-18 war and its aftermath—the Public Health (Smoke Abatement) Act of 1926.

Sir Lawrence Chubb

Secretary of the Coal Smoke Abatement Society, 1900-1929, *Hon. Advisory Secretary, National Smoke Abatement Society,* 1929-1943, *and Hon. Treasurer,* 1943-1948



W. Brownhill Smith

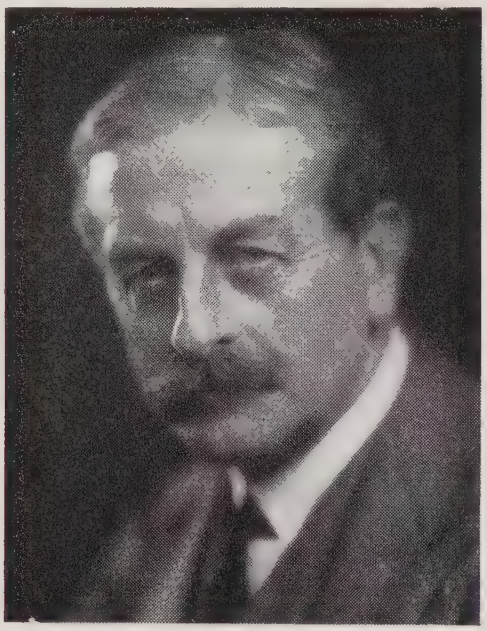
President for many years of the Scottish Branch of the Smoke Abatement League and of the National Smoke Abatement Society. Member of the Glasgow City Council

While the Coal Smoke Abatement Society was concentrating its efforts in the London area the provinces were organizing, and smoke abatement societies were formed in

Leeds (with Professor Cohen, who carried out the classical experiments of the effects of pollution on vegetation), in Glasgow, under the leadership of W. Brownhill Smith, Manchester (where a Noxious Vapours Abatement Association had existed in the latter part of the nineteenth century), and in Sheffield. These groups held a conference in Sheffield in 1909, as a result of which a Smoke Abatement League of Great Britain was formed, with its headquarters in Manchester. For a few years its Honorary Secretary was E. D. Simon, now Lord Simon of Wythenshawe. Among its other active members were Gordon Harvey, M.P., its President, J. W. Graham, Principal of Dalton Hall, Manchester University, and Will Melland, a member of the Manchester City Council. It was a Bill and a memorial to the Government drafted by the League that was supported by the London conference in 1912.

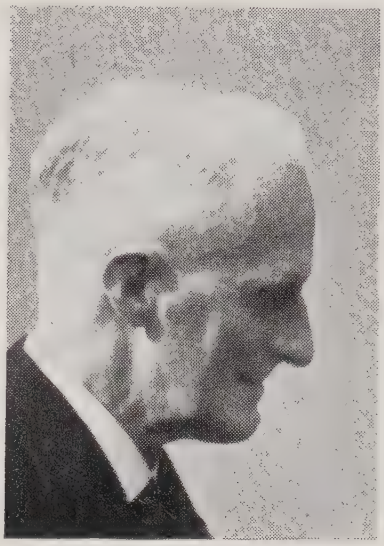
Between the wars

The first world war halted progress in smoke abatement, and it was not until some years afterwards that it began, in a popular way, to move forward again. The Coal Smoke Abatement Society in London, and the League in Manchester, concentrated their efforts first on supplying evidence to the revived Government Committee under Lord Newton, and then on seeking to strengthen (in the face of much opposition from industry), the Bill that was eventually, in 1926, to find its way to the Statute Book as the Public Health (Smoke Abatement) Act. Apart from this the centre of activity moved from London to Manchester, where a revived League organized exhibitions and conferences. The Society in London had depended entirely on individual subscriptions, and had turned its face resolutely against contributions from industry or commerce. The League, on the other hand, made a drive for the support of local authorities and was prepared to receive help from any of the "vested interests"—after making it plain that such support should not interfere in any way with its independence. With Will Melland as its Chairman and Treasurer, the League began to make progress and in 1928 felt confident enough (despite a bank overdraft), and on the strength of promises of £50 a year from four individuals for three years, to engage a full-time secretary. Next year the League and the Society amalgamated to form the National Smoke Abatement Society, with headquarters in Manchester, and with Dr. Des Vœux as President, Will Melland as Chairman and Hon. Treasurer, Sir Lawrence Chubb as Hon. Advisory Secretary, and Arnold Marsh as General Secretary and



Will Melland

Chairman and Hon. Treasurer, Smoke Abatement League and National Smoke Abatement Society, 1926-1934. *Hon. Treasurer,* 1934-1943. *President,* 1943-1945. *Member for many years of the Manchester City Council*



Charles Gandy

Barrister-at-Law, Manchester. Chairman of the National Smoke Abatement Society, 1934-1950. *Originator of the Smokeless Zone principle*

Editor of the quarterly journal, now *Smokeless Air*, which had just been started.

After the inaugural conference at Buxton in 1929, regular annual conferences began, and at that in Leicester in 1930, the Society was honoured for the first time with a civic welcome—to the especial gratification of Dr. Des Vœux, who had so often in the earlier days been snubbed and even derided by the local authorities.

Although the Society's income grew only slowly its constant efforts began to put smoke abatement more and more upon the map, and in 1937, after a highly successful exhibition and conference in 1936 at the Science Museum, South Kensington, headquarters were moved back to London. Progress began to quicken most promisingly —until it was again severely set back by the war in 1939.

During the decade, 1929 to 1939, the Society had to struggle against economic slump, a surplus of coal and unemployment in the mines, and then with national preoccupation with the threat of war. But membership and influence increased, and new ideas were advanced and discussed—particularly the brilliant conception of the smokeless zone by Charles Gandy, the Manchester barrister who succeeded Melland as Chairman. Today, the smokeless zone, or smoke control area, is known everywhere and is an integral part of the Clean Air Act of 1956. The idea of prior approval, to ensure that all new industrial plant would be smoke-free from the start, though familiar overseas, was new to this country and was first advocated by the Society. Also urged, for the first time, was the design and wider use of open fires suitable for coke or other smokeless fuels. In face of the opposition of the coal merchants (recently revised!) the Society more and more criticized the open coal fire as a major source of pollution, and became involved in controversies with them that in the long run did much to spread awareness and acceptance of the case for clean air.

Post War

Though activities were severely cut when the war began in 1939, the Society was kept together, and although for some years there were no meetings an attenuated *Smokeless Air* continued to be published without a break. Then, when "reconstruction" began to be discussed, and became something to which a war-weary country could look forward, the opportunity was taken to emphasize, in various ways, the importance of clean air in post-war planning. No new smoke, said the Society, need be permitted, either in industry or the home, in rebuilding after the war and in the vast new programme of new housing that would be necessary: provided that proper foresight and planning were accepted. The Society was the first (in 1942) to advocate that new types of improved open grate, suitable for any smokeless fuel, should be installed in *all* new houses, and that smoke prevention should be an integral part of any fuel policy. Memoranda were submitted to the official committees that were set up to consider domestic and industrial fuel policies, and by now the case for smoke prevention was so well-known that the recommendations of these committees—Egerton, Simon and Ridley in particular—endorsed and gave official support to the programme advocated by the Society. Many opportunities were unfortunately lost, but before long the smokeless zone principle began to be accepted and one local authority after another included appropriate provisions in Private Acts.

Because of this burgeoning of activity and interest, stimulated by the Society, there was in return a rapid growth in membership and support. A new constitution had to be devised and adopted; the annual conferences grew from a pre-war attendance level of 150 or 200 to 300 or 400, and then on to over 800; the number of affiliated local authorities were trebled, the circulation of *Smokeless Air* grew fivefold and Divisional Councils were established in most parts of the country.

Among those who did much to shape the character and purpose of the Society in these decisive post-war years must be mentioned in particular Charles Gandy (until his untimely early death), and Sir Ernest Smith, who as Hon. Treasurer (after Sir Lawrence Chubb), skilfully increased the Society's fund. A special word of appreciation must be written on Dr. R. Lessing, the only active link between today and the old Coal Smoke Abatement Society. President from 1956 to 1958, and a member of the Beaver Committee, he was the Hon. Secretary of the Conference Committee for the International Exhibition in 1912, and is a member of the Committee that has organized this present Diamond Jubilee Conference.

R. Lessing, C.B.E.

Member of Committee of Coal Smoke Abatement Society, Hon. Secretary of Conference Committee, International Smoke Abatement Exhibition, 1912. Immediate Past-President, and member of Conference Committee for Jubilee Conference. Member of the Beaver Committee on Air Pollution

This growth was in full swing when in 1952 the great London smog, followed by the Beaver Committee, focussed attention as never before on clean air, increasing the Society's opportunities for further work far faster than the means to carry out (a situation which still prevails). To its gratification the recommendations of the Beaver Committee, and the Clean Air Act which followed, crystallized and brought into line with a new climate of opinion, the principles and programme advocated and discussed by the Society.

The introduction by the Government of a Clean Air Bill, based on the Committee's report, came far sooner than would have been the case if there had not been the spur of the Private Member's Bill introduced by Mr. Gerald Nabarro, M.P., and withdrawn only when the Government undertook to take over and introduce their own Bill. Mr. Nabarro's admirable enterprise in so accelerating progress in this way was made possible only through the Society's backing and support.

The new Act has further increased the Society's opportunities and demands for its services in the fields of publicity, education and information. More recently it has changed its name, and its growing status has been reflected in its incorporation as a company limited by guarantee.

Today the Society celebrates its Diamond Jubilee and can do so best by expressing its gratitude to the many individuals, only a few of whom it has been possible to mention here, who conceived, nurtured, and brought to maturity a body dedicated to the single cause of Clean Air. The Society certainly owes much to other organizations, but in the main it has been built up and given the standing it enjoys by individuals who had (and have) a burning desire to restore clean air to their country.

The Future

When the Clean Air Act was passed the Society received a few—but only a few—expressions of congratulation on what was regarded as a successful climax to its years of effort, coupled with the thought that it could now quietly fade away because it would have no more to do. But the Society and its more perspicacious friends were well aware that the new Act was simply the end of one phase, and the beginning of another, in the continuing campaign for clean air. That this was the case is now very clearly evident. The Act has brought distant problems nearer and has created more, and still more work, opportunities and responsibilities.

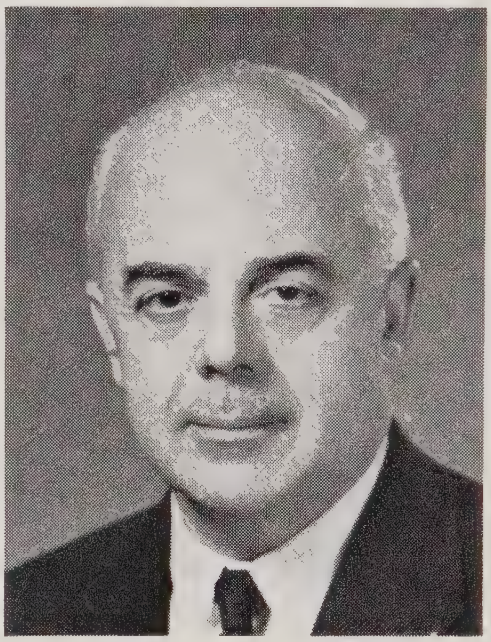
This is not the place for a survey in detail of what the Society may, or should, do in the future, but two at least of its present-day functions are likely to be needed for many years to come. They may be summed up as Policy and Publicity, although of course they overlap and merge at many points.

First, Policy—this stems from the Society's unique position, which it has gradually achieved for itself, as the one independent centre for the promulgation of ideas and forum for discussion on all aspects of air pollution and clean air activity. With its conferences, publications, and divisional activities, the Society can continue and develop such work without great difficulty. It is essentially a continuation of the original work of the Society—to create policies and programmes and to make them known, accepted, and brought into being.

Second, Publicity—this is the work which in certain aspects is relatively new and is now rapidly growing—publicity, education, the provision of information, library services, and so on, to all and every section of the community, from the local authority and the industrialist to the technologist and research worker; from those who make and administer the law to the man in the street and the woman in the home who have to observe it. It is becoming necessary because of the far-reaching effects of the new Act upon all who live in urban areas, and it is work that, to be done effectively, must cost a great deal of money. Because of that the Society can so far only touch its fringes.

It is work that should extend widely to the general public, in the form of mass publicity, and also along specialized lines to those who need technical and other information. It can also be extended by activities of which an excellent example is the present Diamond Jubilee Conference and Exhibition. In short, new fields of enterprise, all designed to promote clean air, lie open to the Society during the coming years.

The present Conference, with its notable and gratifying response from overseas, suggests a *third* purpose for the Society's future—to co-operate in, and perhaps, even, as the oldest organization of its kind in the world, to lead in promoting international co-operation and mutual assistance in the study and attack on a problem that concerns an increasing number of nations.—*A.M.*

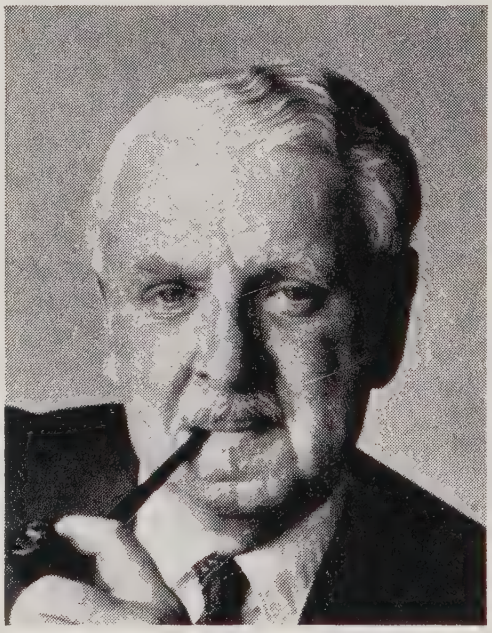


Stanley E. Cohen

Hon. Treasurer, National Society for Clean Air. Proposed celebration of Diamond Jubilee by an International Conference. Member, and Vice-Chairman of Health Committee, Court of Common Council, City of London

J. J. Matthews

Chairman of Conference Committee, National Society for Clean Air since 1951; Hon. Secretary, South-East Division. Chief Public Health Inspector, Acton



Arnold Marsh, O.B.E.

General Secretary, Smoke Abatement League and National Smoke Abatement Society from 1928. Director and Secretary, National Society for Clean Air. Editor of "Smokeless Air" since its inception in 1929

National Society for Clean Air

and

National Smoke Abatement Society

1929—1959

Present and Past Officers, &c.

President: Sir Hugh Beaver, K.B.E.

Senior Vice-President: Sir Graham Sutton, K.B.E.

Immediate Past-President: Dr. R. Lessing, C.B.E.

Past-Presidents: Dr. H. A. Des Vœux,* Will Melland,* Sir George Elliston,* Lord Simon of Wythenshawe, Dame Vera Laughton Matthews, D.B.E., Alderman Professor F. E. Tylecote, C.B.E., Sir Ernest Smith, C.B.E. (**Deceased*)

Hon. Treasurer: Stanley E. Cohen, C.C.

Past-Hon. Treasurers: Will Melland, Sir Lawrence Chubb, Sir Ernest Smith

Chairman of Council: Dr. J. S. G. Burnett

Past Chairmen of Council: Will Melland, Charles Gandy, S. N. Duguid, J.P., Dr. W. R. Martine, O.B.E., T.D., F. J. Redstone

Deputy Chairmen of Council: John Innes, Dr. J. L. Burn

Standing Counsel: W. R. Hornby Steer

Vice-Presidents: Viscount Samuel, P.C. S. N. Duguid, J.P., Alderman Dr. C. A. Bence, Commander Colin Buist, M.V.O., H. G. Clinch, M.B.E., G. R. Farquharson, T. C. Finlayson, C.B.E., Councillor Eric Gibbons, Dr. Harold Hartley, C.B.E., John Innes, Dr. J. Johnstone Jervis, Dr. R. H. H. Jolly, James Law, Alex W. Lee, Dr. W. R. Martine, O.B.E., T.D., Alderman J. J. Milton, O.B.E., Alderman F. W. Perry, J.P., F. J. Redstone, Allan W. Ritchie, M.B.E., Alderman F. J. Timmis, O.B.E.

Chairmen of Committees:

Conference: J. J. Matthews

General Purposes and Finance: Dr. J. S. G. Burnett

Parliamentary and Local Government: G. W. Farquharson

Publicity: I. Lewis, M.B.E.

Technical: Dr. T. P. Colclough, C.B.E.

Hon. Solicitors: Messrs. Bell, Brodrick and Gray

Hon. Auditors: Messrs. Geo. Little, Sebire and Co.

Bankers: The District Bank Ltd.

Divisional Councils : Chairmen and Secretaries

Scottish: John Innes, Norman Fraser

North West: S. N. Duguid, V. Hewitson

North East: Alderman B. Young, G. W. Tate

Yorkshire: A. C. Saword, James Goodfellow

West Midlands: Clr. W. A. N. Jones, G. W. Farquharson

East Midlands: G. A. Hiller, A. Wade, M.B.E.

South East : Alderman C. H. Smith, O.B.E., J. J. Matthews

South Wales and Monmouthshire: Alderman W. A. Hancock, A. J. Dalton

Headquarters Staff:

Director, Secretary and Editor: Arnold Marsh, O.B.E.

Administrative Secretary and Exhibitions Officer: L. Nevard

Information Officer and Librarian: H. C. F. Kapps

Accountant: Mrs. D. M. Wolfe

Administrative Assistant: J. C. Mahoney

Secretarial Assistants: Mrs. S. M. Burden, Miss M. Rawson, Miss J. Johnston, Miss B. Bull

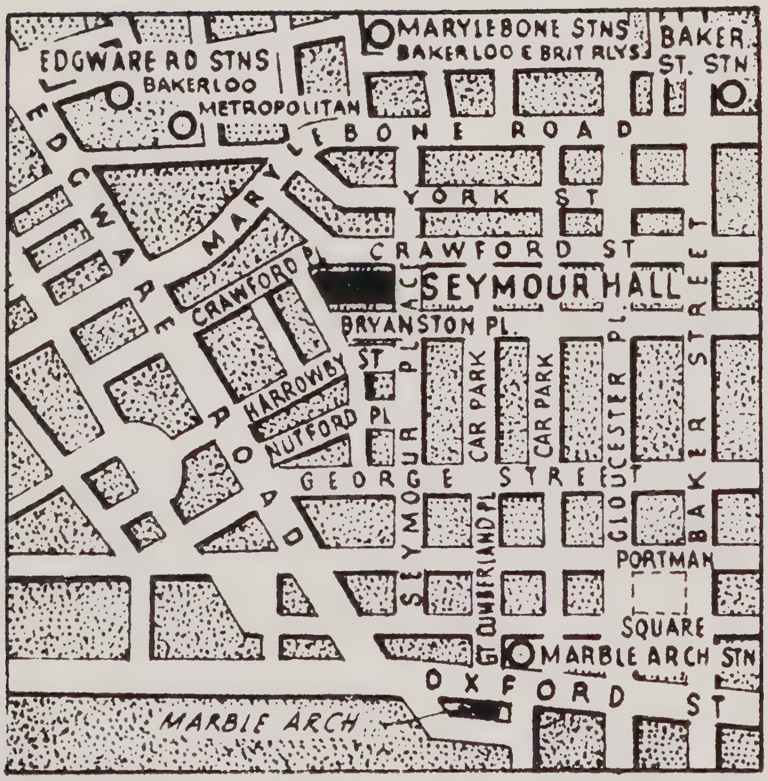
Invitation

The Society invites the Membership of all who are interested in this International Conference or in the Exhibition. Membership is open to any individual, corporate body or local authority.

Members receive the Society's publications, participate in all its activities, including elections for office, and may call on the Society's Publicity, Library and Information Services. Individual membership from 15s per annum. Corporate membership from 12 guineas; local authorities according to population. Sustaining Membership from £100 per annum. Associate membership at any subscription less than that for full membership.

Ask at Information Office, Seymour Hall, for full details, or write to the Society's offices: Palace Chambers, Bridge St, London, S.W.1.

HOW TO REACH SEYMOUR HALL



Bus Routes to:

Oxford St and Marble Arch—6, 7a, 8, 12, 13, 15, 23, 88, 113, 137, 260, 289, 291, 294

Wigmore St and Portman Square—592, 159

Marylebone Rd—18b, 27, 176

Edgware Rd—6, 7s, 8, 15, 16, 36, 36a, 260, 291, 294

Nearest Underground Stations:

Marble Arch, Baker St, Edgware Road.

Marylebone (Midland and Eastern Regions)

Car Parks:

Free Parking in Bryanston Square (Normally very crowded)

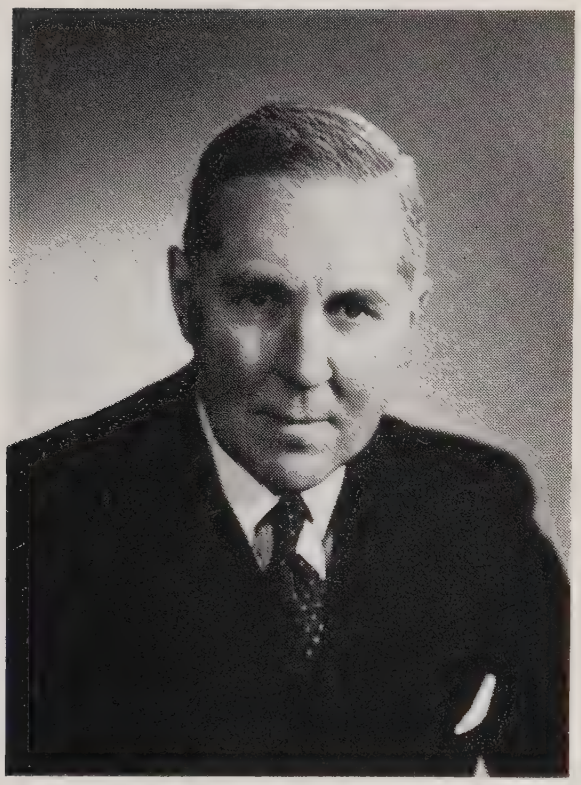
Express Car Park, between George St and Portman Sq, 3*s* per day

Oxford Street and Marble Arch are approximately 10 minutes walking distance

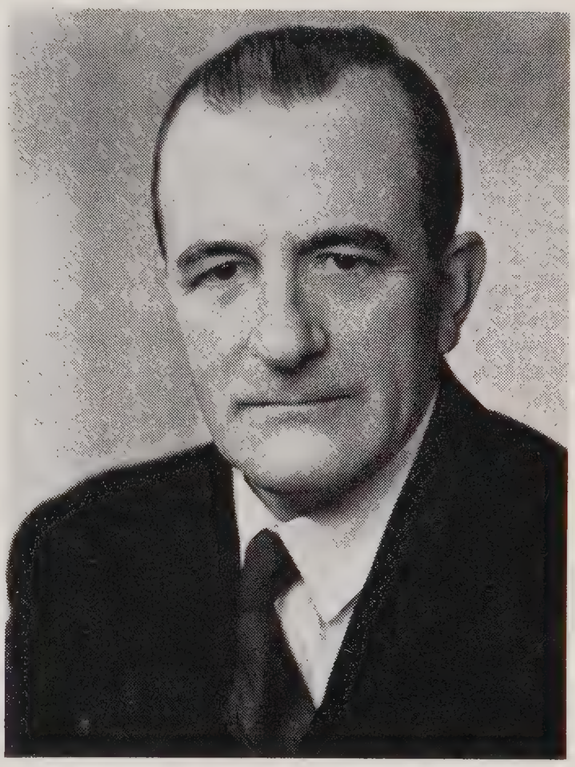
The Rt. Hon. the Lord Mayor of London
Sir Harold Sydney Gillett, M.C.

who will open the Conference and Exhibition
at 10.30 a.m. on Tuesday, 20th October

Openers of Sessions

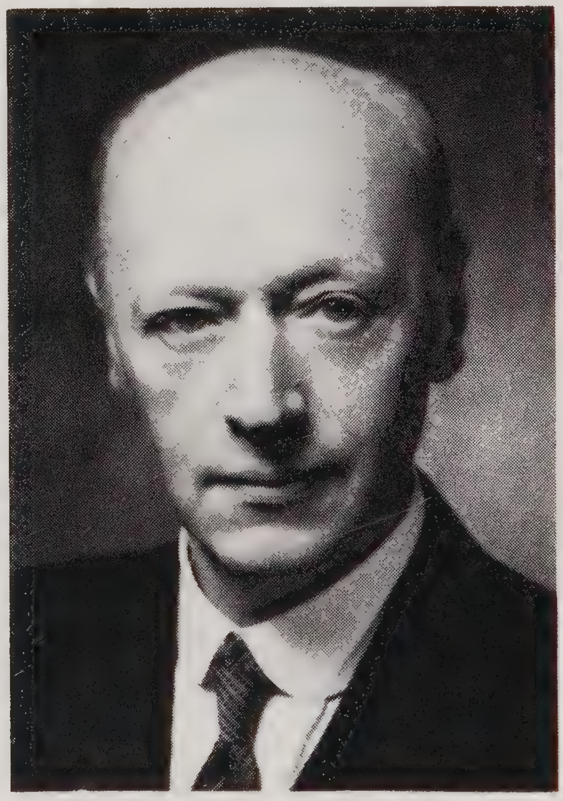


The Rt. Hon. Henry Brooke
Minister of Housing and Local Government
Chairman of the Clean Air Council



The Rt. Hon. Lord Mills
Minister of Power

The Rt. Hon. Derek Walker-Smith
Minister of Health



Sir David Anderson
Chairman of the Clean Air Council for Scotland

The Mayor of St. Marylebone and Chairmen of Sessions

The Mayor of St. Marylebone
Councillor Lt.-Col. H. C. S. Thomson, O.B.E.
who will welcome the Lord Mayor and Conference to the Metropolitan Borough

Dr. J. S. G. Burnett
Chairman, Session II
Chairman of the Executive Council

Dr. T. P. Colclough, C.B.E.
Chairman, Session III
Chairman of the Society's Technical Committee

John Innes
Chairman, Session IV
President, Scottish Division and Deputy Chairman, Executive Council

Dr. J. L. Burn
Chairman, Session V
Deputy Chairman, Executive Council

Conference Information

OPENING OF SESSIONS

All delegates are requested to take their seats before the time of opening for each session and prior to the entry of the Platform party.

SESSIONAL PROCEDURE

After the opening procedure as shown in the programme for Sessions II to VI the meeting will be open for questions and discussions related to the papers included in that session. There will be no discussion in Session I. Those wishing to participate in the discussions should complete and hand in one of the coloured Discussion Cards (if possible before the session begins). When called upon by the Chairman they should proceed to the microphone. Speeches may have to be limited in time, according to the number wishing to participate, and must not exceed any limit that may be given by the Chairman.

On the Thursday afternoon, Session VI, there will be a final discussion in which delegates may speak on any Paper or on the conference in general. Written contributions to the discussions, from any delegate who is unable to speak during the sessions, will be accepted for inclusion in the final *Proceedings*.

THE PAPERS

A volume of preprints of the Papers to be discussed will be sent without charge to all registered delegates. Additional copies for delegates, or for others, may be obtained at a price of £1 each, from either the Society's office or during the Conference at the Bookstall. If any Papers are received too late for inclusion in the Preprints they will, if possible, be printed or duplicated separately and will be available at the Conference.

PROCEEDINGS

The Conference Papers, together with the Presidential and other Addresses, reports of discussions, etc., will be published in due course after the Conference. Speakers who wish their contributions to the discussions to be included in this volume should hand a copy of their remarks (in English) to a Steward during the Conference or send it to the Society's offices as soon as possible afterwards. One copy of the *Proceedings* will be sent to all delegates who have subscribed for it. Additional copies can be purchased at 30s. each.

DISCUSSIONS—LANGUAGE

The Conference will be conducted in English. (It has not been possible to arrange for a simultaneous translation service). Overseas delegates who wish to speak and who desire the assistance of an Interpreter should inquire beforehand at the Information Desk in the entrance hall.

LIST OF DELEGATES

Copies of a printed list of Delegates will be distributed at the Conference. Information about the conference addresses of delegates will be available from the Register of Delegates at the Information Desk in the entrance hall. To enable this Register to be as complete as possible all delegates are requested to fill in and hand to a Steward at the first session they attend, the Registration Card to be enclosed with this handbook.

BADGES

All Delegates are requested to wear their Conference Badges during the sessions. A white badge indicates a United Kingdom delegate; those for Overseas delegates will be blue, with the name of their country added. Owing to the time needed to produce these badges, it is regretted that it may not be possible to supply them to delegates who registered after 10th September.

EXHIBITION

With the exception of the Stands in the Conference Hall, which will be closed during sessions, the Exhibition will be open daily from 9.00 a.m. to 6.00 p.m. Entrance to the Exhibition is open and free to all members of the Society and to the general public, and members and delegates are asked to invite their friends and colleagues to visit it.

FILM SHOWS

The Film Shows, about which Delegates have received separate information, to be held each afternoon at 4.45 p.m. in the David Fisher Hall, Crawford Place, require a ticket of admission, Any delegates or others who have not asked for and received a ticket should inquire at the Information Desk.

LUNCHEON AND REFRESHMENT FACILITIES

Seating for luncheons in Seymour Hall is limited and many delegates will wish to go outside to restaurants in the area. The following list—by no means exhaustive—is intended as a guide to some of the more popular establishments in the locality.

In Seymour Hall

The Balcony Restaurant—Luncheons from 12.45 to 2.00 p.m.

The Bryanston Bar—Luncheons from 12.00 to 2.30 p.m.; light refreshments from 11.30 a.m. to 6.30 p.m.

Hotels in the Area

Bryanston Court, Great Cumberland Place; The Cumberland, Marble Arch; Great Western, Paddington Station; The Mostyn, Portman Street.

Restaurants in the Edgware Road Area

Lyons' Corner House, Marble Arch; Chez Pierrot, Seymour Street; Fawcett Court Restaurant, Edgware Road; Henry's (Continental), junction of Nutford Place and Edgware Road; Mysore (Indian), Praed Street; Park West Restaurant, Edgeware Road; Parisien Grill, Edgware Road; New Great Indian Restaurant, Seymour Place; the Lotus House (Chinese), Edgware Road; the Continental Restaurant, Dudley Court, Edgware Road.

Restaurants in Baker Street

Dutch Oven, Harry Gold (Kosher), Ici Paris, Berkeley Court, Quality Inn, Chiltern.

Restaurants in Oxford Street

Lucullus (Polish) (opposite Selfridge's); Selfridges.

Public Houses Serving Lunch

The Henry Finch, Crawford Place; 199 House, Edgware Road; The Crown, Edgware Road; The Globe, Marylebone Road; The King's Arms, Edgeware Road; The Volunteer, Baker Street; The Westbourne Arms, junction of Eastbourne Terrace and Praed Street.

CLOAKROOMS

Ladies' and gentlemen's cloakroom facilities are available downstairs from the main entrance hall. (6d. charge for hats and coats, etc.).

BANK

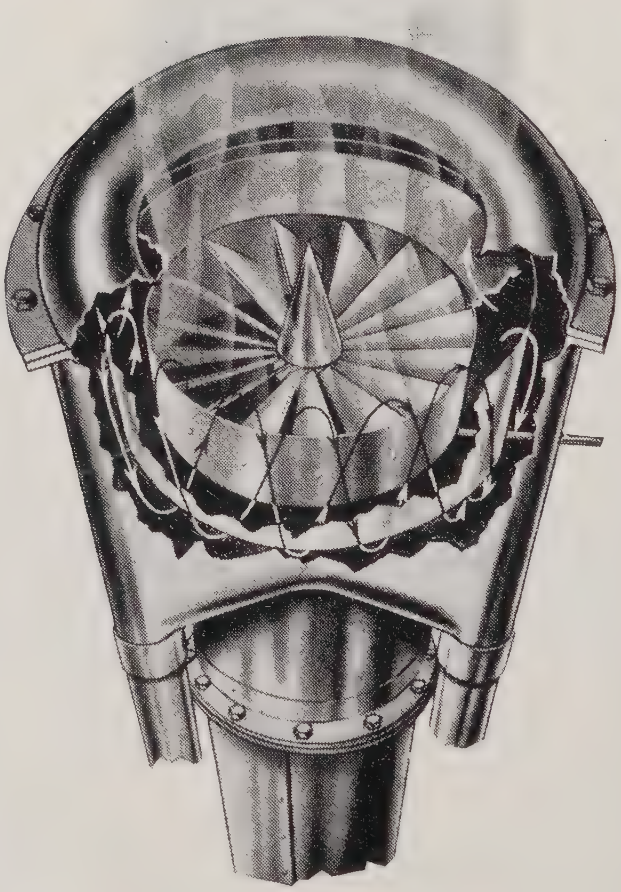
Full banking facilities will be available to all attending the Conference or Exhibition, from the District Bank Ltd., at Stand 38 in the Seymour Place, (main) Entrance Hall.

Six good reasons for choosing a

CORY GRIT ARRESTER

1 **LOW** cost
2 **HIGH** efficiency, complying with the requirements of The Clean Air Act
3 **LOW** pressure drop. NO FANS REQUIRED
4 **RAPID INSTALLATION** - 3 have been fitted at one plant in 24 hours
5 **COMPACT AND EASILY ADAPTABLE** to any site conditions. Fitted at top, base of stack or in the ducting leading to it
6 **EASE OF MAINTENANCE.** All parts easily removable

COMBUSTION EQUIPMENT LTD.
61 Belsize Lane, London, N.W.3 *Swiss Cottage 4462/3*



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SMOKE BURNERS LTD
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1 Remove all fear of complaints from the Smoke Inspector under the Clean Air Act.
2 Give a working efficiency and a coal saving that will repay its costs in a few months.
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*The cost (including fitting) for a *Lancashire Boiler is well under £300 and we fit on a basis of " no cure—no pay ".*

** Can be fitted to handfired, automatic sprinkler or shovel stoker.*

Install the famous

IDEAL 'Autocrat'

DOMESTIC BOILER

★ **HIGH EFFICIENCY**

★ **ATTRACTIVE DESIGN**

★ **SOLID CONSTRUCTION**

★ **THERMOSTATIC CONTROL**

★ **WARMS THE KITCHEN**

★ **CLEAN IN OPERATION**

How can you have all the hot water you need? At the lowest price? The answer: install an Ideal Autocrat. This modern domestic boiler is unbelievably economical. It burns clean inexpensive coke (or other solid smokeless fuels) and with its host of advanced features it reduces attention to a minimum.

Running costs are cut by thermostatic control. And the Autocrat itself is wonderful value. The smaller No. 1 costs only £23! With its clean modern design, solid construction and excellent finish, the Ideal Autocrat is a fine compliment to your kitchen.

With an Autocrat your kitchen is kept comfortably cosy. A gentle warmth given off by the smoke pipe and the top-plate in no way impairs the boiler's efficiency as the heat is not taken from the waterway.

And the Autocrat can help to warm your house too. If hot water demands are moderate the smaller model, the No. 1, will heat a radiator or towel rail. The larger No. 2A can heat up to three radiators as well as supplying hot water in abundance. Ideal domestic boilers without thermostatic control are available at lower prices.

No. 1 'Autocrat' *with stoking tools* **£23.0.0** No. 2A 'Autocrat' *with stoking tools* **£37.10.0**

Prices increased for Ireland, Channel Isles and Isle of Man

For illustrated literature and address of local stockist write to:—

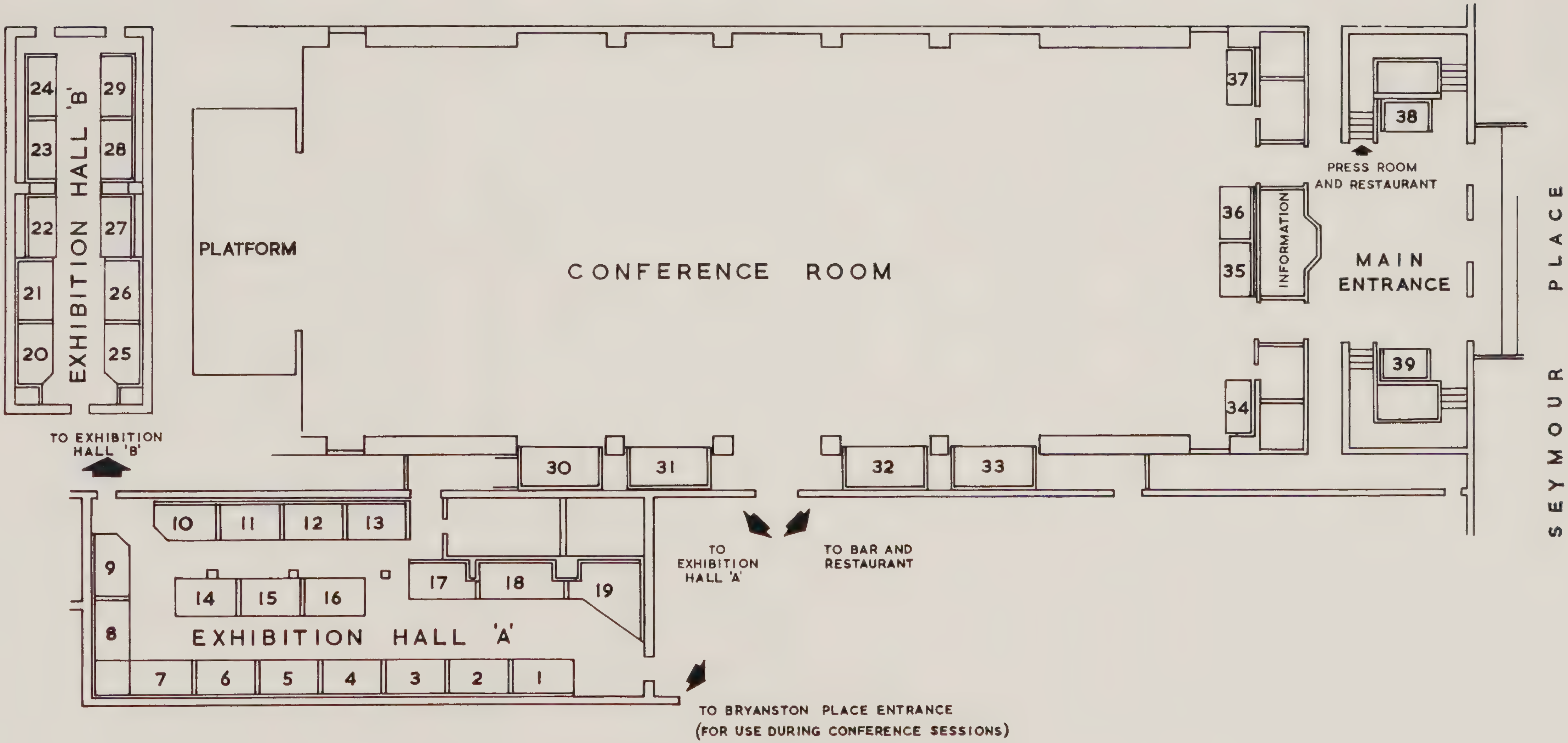
IDEAL BOILERS & RADIATORS LIMITED · IDEAL WORKS · HULL

IDEAL-Standard

453

Plan of Seymour Hall

Showing Position and Numbers of Exhibition Stands



THE INTERNATIONAL CLEAN AIR CONFERENCE

1959

Programme

All Sessions to be held in the Seymour Hall, Seymour Place, London, W.1.

Tuesday Morning, 20th October

9.00 a.m. Exhibition and Information Office open.

10.30 a.m. **SESSION I**

Chairman: Sir Graham Sutton, F.R.S.

Welcome by His Worshipful the Mayor of St. Marylebone, Councillor Lt.-Col. H. C. S. Thomson, O.B.E.

Opening of the Conference and Exhibition by the Rt. Hon. the Lord Mayor of London, Sir Harold Sydney Gillett, M.C.

Address by Sir Graham Sutton, Senior Vice-President*

12.00 approx. Adjournment

Tuesday Afternoon, 20th October

2.30 p.m. **SESSION II**

Chairman: J. S. G. Burnett, M.D., D.P.H.

NATIONAL AIR POLLUTION PROBLEMS, LEGISLATION, EDUCATION, ETC.

Opening of the Session by the Minister of Housing and Local Government, the Rt. Hon. Henry Brooke.

Presentation for discussion of the following Papers:

Rapporteur: Professor A. B. Semple, V.R.D., M.D., D.P.H. (Medical Officer of Health, Liverpool)

Opener: J. O. Buxell (World Health Organization)

1. P. D. Coates: Air Pollution Legislation and Administration in Great Britain.
2. C. Brosset, H. Ronge and R. Spaak: A Planned Investigation of Air Pollution in Gothenburg, Sweden.
3. J. H. Carter: The Successful Anti-Smoke Programme of St. Louis, U.S.A.
4. F. E. Dawson: Legislation and Administration in Small States (Eire).
5. Federal Ministry of Labour, Germany: The Present Degree of Air Pollution and the Relevant Laws and Regulations in Force in the Federal Republic of Germany.
6. K. Guthmann: Air Pollution Problems in the Federal Republic of West Germany.
7. E. C. Halliday: The Development of Public Opinion on Air Pollution in South Africa.
8. Institute of Public Health, Japan: Public Opinion and Education in Japan.
9. Institute of Public Health, Japan: Legislation in Japan.
10. E. Leclerq: Some Activities in Belgium in the Field of Atmospheric Pollution During the Last Five Years.
11. W. Lindberg: Atmospheric Pollution Problems in Norway.

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* *It is regretted that, for health reasons, the President will be unable to be present and to give his Presidential Address, as previously announced. Sir Graham Sutton, Senior Vice-President, has kindly agreed at short notice to act in his place.*

12. A. Marsh: Public Opinion and Education for Clean Air in the United Kingdom.
13. T. Müller: Investigation on Air Pollution in Basle 1957-1959 (Switzerland).
14. J. Polacek: Clean Air in Czechoslovakia and Means for Improvement of Today's Conditions.
15. O. Schmidt: Parliamentary Initiative for the Prevention of Air Pollution in Germany.
16. L. Schreibeis: Progress and the Future in Air Pollution in Allegheny County, U.S.A.
17. K. Spurny and E. Lochmanova: Air Pollution Problems in Czechoslovakia.
18. F. Tetzlaff and R. C. Graber: Air Pollution Legislation and Administration in the United States.
18a. Y. Queret: The French Association for the Prevention of Air Pollution.

4.30 p.m. approx. Close of Session.

4.45 p.m. Film Show at the David Fisher Hall, Crawford Place, (for ticket holders only).

Wednesday Morning, 21st October

10.00 a.m.

SESSION III

Chairman: T. P. Colclough, C.B.E., D.SC., D.MET.

TECHNICAL CONTRIBUTIONS

Opening of the Session by the Minister of Power, the Rt. Hon. Lord Mills, K.B.E.

Presentation for discussion of the following Papers:

Rapporteur: G. Nonhebel, B.A., F.R.I.C., M.I.CHEM.E., F.INST.F.

Opener: W. C. Turner, M.D., B.S., M.R.C.S. (Medical Officer of Health, Poplar).

19. G. H. Daniel: The Growth in World Fuel Consumption and its Threat to Clean Air (Great Britain).
20. J. Böhm: Fly-ash Collection in Plant Using Second-Rate Fuel (Czechoslovakia).
21. J. Bronowski: The Development of New Smokeless Fuels (Great Britain).
22. R. L. Cooper: The Coking Industry: its Problems and its Contribution to Clean Air (Great Britain).
23. R. Delbruyere: A Commended Solution to the Problem of Air Pollution (Belgium).
24. S. N. Duguid: Education as an Aid to Industrial Smoke Elimination (Great Britain).
25. Gas Council: Gas in Industry (Great Britain).
26. K. Guthmann: Removal of Dust from Brown Fumes in Oxygen-blowing Steelworks (West-Germany).
27. K. Guthmann: Technical Removal of Dust as Dealt with by the European Coal and Steel Community (West Germany).
28. J. W. Jacquest: The Problems of Air Pollution by Diesel Road Vehicles (Great Britain).
29. Kingsley Kay: Environmental Arsenic Contamination and Control in Smelting Operations (Canada).
30. H. Kettner: Cheaper Cleaning Equipment for Air Pollution Control (West Germany).
31. P. Lasserre: The Problem of Suppressing Dust and Gaseous Moisture at Emission Points in Relation to Air Pollution (Belgium).
32. B. Lees: The Elimination of Acidic Smuts (Great Britain).
33. G. Underwood, D. Watson, S. G. McConnell and M. W. Thring: Fundamentals of Smoke Emission From Low Temperature Furnaces (Great Britain).
34. S. Weinberg and W. Randall: Coal and Modern Equipment in Relation to Economy and Clean Air (Great Britain).

12.30 p.m. approx. Adjournment.

Wednesday Afternoon, 21st October

2.30 p.m. SESSION IV

Chairman: John Innes

OBSERVATION, INVESTIGATION AND MEASUREMENT OF AIR POLLUTION

Opening of the Session by the Chairman of the Clean Air Council for Scotland, Sir David Anderson, PH.D., F.R.S.E.

Presentation for Discussion of the following Papers:

Rapporteur: E. T. Wilkins, PH.D., M.SC. (Department of Scientific and Industrial Research)

Opener: Albert Parker, C.B.E., D.SC.

35. H. Berge: International Problems Relating to the Control, Inspection and the Assessment of Air Pollution (West Germany)
36. Dr. Besson and J. Pelletier: Atmospheric Pollution in the Paris Area (France).
37. W. G. Cummings and M. W. Redfearn: The Measurement of Sulphur Dioxide in the Atmosphere Near Power Stations (Great Britain).
38. A. Giovanardi, E. Grosse and E. de Fraja Frangipane: Researches on the Atmospheric Pollution of the City of Milan (Italy).
39. D. H. Grindell: Monitoring Flue Dust Surface Area (Great Britain).
40. E. C. Halliday: Research on Air Pollution in South Africa.
41. H. O. Hettche: Contributions to the "Smog" Problem (West Germany).
42. Institute of Public Health, Japan: Research and Investigation in Japan.
43. K. R. Johnson: The Durban Cleaner Air Campaign (South Africa).
44. H. Kirste: Need for Standardized Methods in Air Pollution Surveys (West Germany).
45. H. Kirste: Dust Measurements to Determine the Sources of Emissions Damaging Crops (West Germany).
46. D. H. Lucas: The Calculation of Sulphur Dioxide and Smoke Concentration from Domestic Sources in Cities (Great Britain).
47. B. Paccagnella: The Investigation of Air Pollution in Padua During the Years 1955-1958 (Italy).
48. L. Petrilli: Air Pollution in the City of Genoa (Italy).
49. K. Schwarz: T. Gilbert and E. Ratzki: Research into Air Pollution in the City of Essen (West Germany).
50. K. Spurny, M. Polydorova and J. Pixova: Determination of Particle Sizes in Industrial Aerosols of the City Air (Czechoslovakia).

4.30 approx. Close of Session.

4.45 p.m. Film Show at the David Fisher Hall, Crawford Place (for ticket holders only).

8.00 p.m. Reception at Guildhall by the Rt. Hon. the Lord Mayor of London (by invitation ticket only).

Thursday Morning, 22nd October

10.00 a.m. SESSION V

Chairman: J. L. Burn, M.D., D.HY., D.P.H.

RESEARCH AND INTERNATIONAL CO-OPERATION

Opening of the Session by the Minister of Health, the Rt. Hon. Derek Walker-Smith, TD., Q.C.

Presentation for Discussion of the following Papers:

Rapporteur: Dr. C. Forrester, F.R.I.C., F.INST.F., F.R.S.E., (Ministry of Power)

Opener:

51. J. O. Buxell: Some Conclusions on the Extent and Possibilities of Co-operation Research in Europe on Air Contaminants (World Health Organization).

52. M. Clifton, D. Kerridge, J. Pemberton, W. Moulds and J. K. Donoghue: Morbidity and Mortality from Bronchitis in Sheffield in Four Periods of Severe Air Pollution (Great Britain).

53. Ellis F. Darley: Research on Damage to Vegetation from Air Pollution at the University of California (U.S.A.).

54. R. Dickinson and D. E. Kimber: An Electro-Precipitator for the Assessment of Domestic Smoke (Great Britain).

55. R. Dickinson and D. E. Kimber: Some Measurements of the Smoke Emission from Domestic Appliances (Great Britain).

56. Gas Council: The Emission of Oxides of Sulphur from Domestic Appliances (Great Britain).

57. R. Harth and W. Seidl: Documentation of Air Pollution Requires International Co-operation (West Germany).

58. H. Heiman, A. C. Stern and R. A. Taft: Current Status of Air Pollution Research in the United States.

59. P. C. G. Isaac: Some thoughts on International Co-operation in Air Pollution Research (Great Britain).

60. W. Kelm: Steps Taken by Local Authorities in the Federal Republic of Germany Towards Combating Air Pollution.

61. K. Lenhart and Dip. Ing. Thieme: Problems of Smoke Emission of Coal-Fired Single Stoves (West Germany).

62. P. J. Meade: Inversions and Air Pollution (Great Britain).

63. Y. Nose: Effects of Exposure to Air Pollution on Community Health (Japan).

64. L. Petrilli: Observations on the Relations Between Air Pollution and Public Health (Italy).

65. A. E. Reif: Carcinogenesis by Atmospheric Pollution (U.S.A.).

66. R. S. Scorer: The Photography of Air Pollution (Great Britain).

67. G. Spurr: The Penetration of Inversions by Hot Plumes (Great Britain).

68. R. E. Waller and B. T. Commins: Air Pollution in the City of London (Great Britain).

69. E. F. Wolf, H. L. von Hohenleiten and M. B. Gordon: The Use of Transparent Scale Models in the Design of Dust Collector and Gas Duct Systems for Coal-Burning Electric Generating Stations (U.S.A.).

12.30 p.m. approx. Adjournment.

Thursday Afternoon, 22nd October

2.30 p.m.

SESSION VI

Chairman: Stanley E. Cohen, C.C., F.R.S.H.

FINAL DISCUSSION

Reviews, by their respective Rapporteurs of Sessions II to V.

Final Open Discussion.

Concluding Address by T. C. Bailey (Immediate Past President, Institute of Fuel)

Votes of Thanks.

4.00 p.m. approx. Close of Session and of proceedings at Seymour Hall.

Friday, 23rd October

Visits, as detailed in programme sent to all delegates.

Every single industry…

Every single industry in Britain, from farming to atomic energy, depends on steel. So everyone benefits from the efficiency and low prices of Britain's go-ahead Steel Industry.

THE BRITISH IRON AND STEEL FEDERATION

THE EXHIBITION

The Exhibition will be open from 9 a.m. to 6 p.m. on Tuesday, Wednesday and Thursday, 20th to 22nd October 1959. During Conference Sessions the Exhibits in the Conference Hall will be closed, and access to the Exhibits in Halls "A" and "B" as marked on the plan, will be from the Bryanston Place entrance only.

LIST AND DESCRIPTION OF EXHIBITS

The information given in this list has been supplied by the Exhibitors and no responsibility for any of the statements or descriptions can be accepted by the National Society for Clean Air.

Stand No.

24 THE BRITISH IRON AND STEEL FEDERATION, Steel House, Tothill Street, London, S.W.1

The B.I.S.F. represents some 350 companies engaged in the manufacture and processing of iron and steel.

In 1957 the industry produced 14·3 million tons of iron and 21·7 million tons of steel. Transportation, handling and stocking of raw materials for this scale of operations inevitably lead to some local air pollution. In addition, melting and rolling operations are carried out at high temperatures; considerable quantities of fuel are required, producing high velocity waste gases loaded with particulate matter.

A clear distinction must be drawn between pollution from simple combustion processes and that from metallurgical operations. Because of increased fuel efficiency and changes in pattern of fuels used, the former no longer constitutes a serious nuisance at modern steel works. Metallurgical problems remain however and, for this reason, certain of the industry's processes have been placed under the supervision and control of the Alkali Inspectorate, whose District Inspectors are particularly well situated for effective operation in steelmaking areas.

Tremendous progress has been made. For instance, air pollution by dirty blast furnace gas represented a widespread nuisance some years ago, but the industry developed a technique for effectively cleaning the gas, and practically the whole daily production of 5,000,000,000 cubic feet is now made cleaner than ordinary air. Replacement cost of this cleaning plant is of the order of £20 million.

All companies have been advised to appoint a technically trained person with responsibility for air pollution matters; the industry is making a co-ordinated approach through its Air and River Pollution Committee and research organization (B.I.S.R.A.), and is co-operating and consulting with other countries.

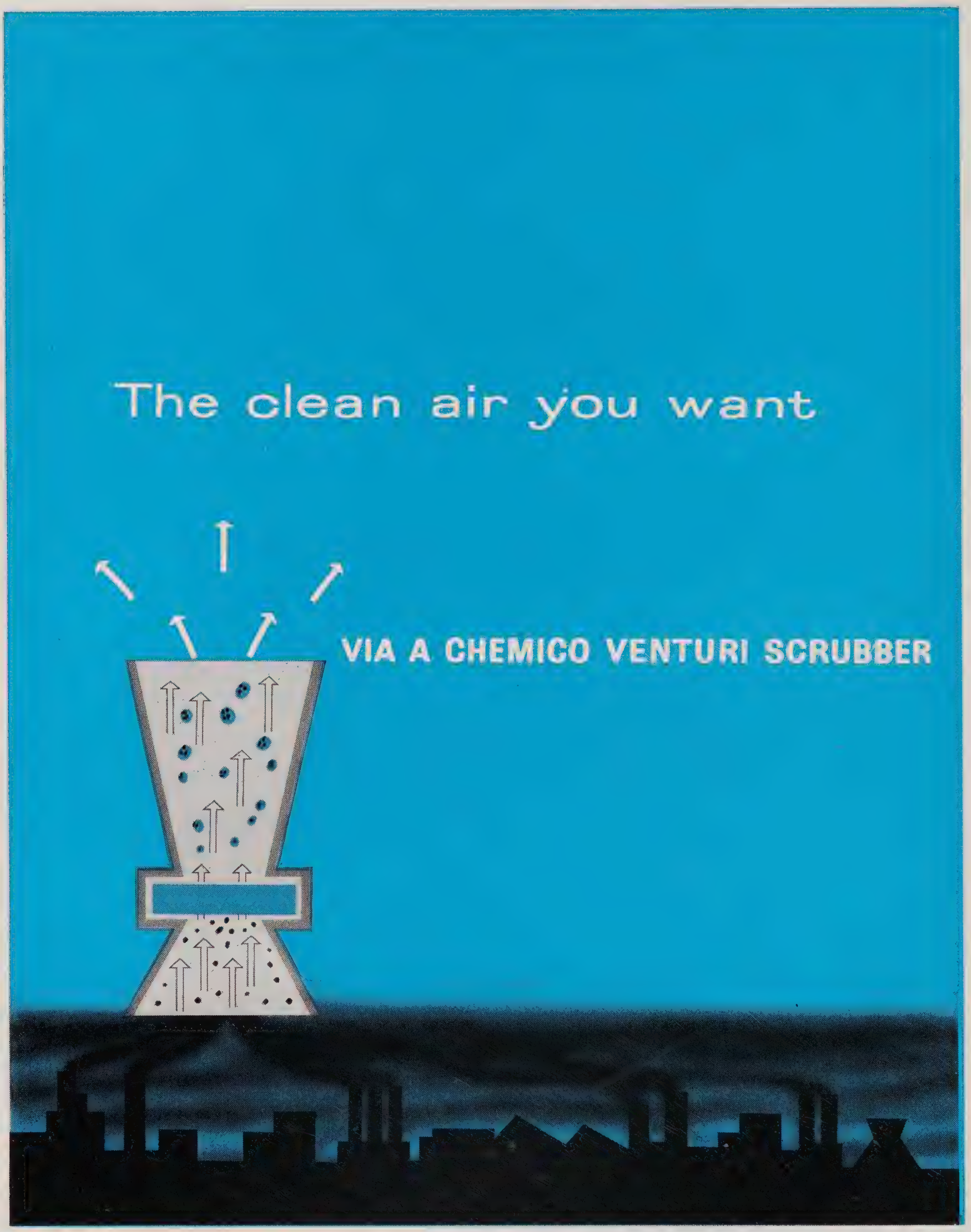
What of the future? One new feature is the application of oxygen to steelmaking, leading to problems which are under intense study. The industry's aim in this, as in the problems already solved, is to be efficient and a good neighbour.

12 BRITISH TRANSPORT COMMISSION, Publicity Division, 222 Marylebone Road, London, N.W.1

The British Transport Commission illustrates by means of photographs and models the aid which their Rail Modernization plan will give to air purification.

20 and 21 CENTRAL ELECTRICITY GENERATING BOARD, Bankside House, Sumner Street, London, S.E.1

The Central Electricity Generating Board's exhibit features various items of equipment and experimental apparatus as applied to the study and control of power station chimney emissions. There will be on view an actual balloon as used in power station chimney plume tracking.


The clean air you want
VIA A CHEMICO VENTURI SCRUBBER

CHEMICO

19 **CHEMICAL CONSTRUCTION (G.B.) LIMITED, 9 Henrietta Place, London, W.1**

Chemical Construction (G.B.) Limited known internationally as Chemico are exhibiting their range of scrubbers.

Chemico gas scrubbers include the venturi scrubbers which are an effective and economical way to solve difficult scrubbing jobs such as the removal of sub-micron dust, fumes and mists. The P.A. Venturi principle of operation is shown by an animated panel. Also on view is the new S.F. Venturi which is especially suitable for the removal and elimination of hard-to-handle sticky solids from gases. This scrubber permits recycling of heavy slurries and recovery of concentrated process materials from gases.

The application of the P.A. Venturi for cleaning blast furnace or similar gases is represented by a transparent working model permitting the operation to be observed, this model uses the later type of whirl vane separator developed for high de-entrainment efficiency on large scale units.

For the less difficult problems, information and data are provided on the Cyclonic scrubber which is effective for the removal of dusts and liquid aerosols which are plus-micron in size or larger; also on problems requiring an absorption action such as the removal of obnoxious odours and low concentration of corrosive acid fumes.

A new method of removing SO_2 from stack gases will be shown for the first time. Ammonia gas is added to stack gases forming ammonium-sulphur salts which are removed in an electrostatic precipitator.

6 and 7 **COAL UTILIZATION COUNCIL, 3 Upper Belgrave Street, London, S.W.1, and at Aberdeen, Birmingham, Bristol, Cambridge, Cardiff, Edinburgh, Glasgow, Leeds, Manchester, Newcastle upon Tyne, Nottingham, Plymouth, Reading and Tunbridge Wells**

The Coal Utilization Council is a non-commercial organization founded in 1932. It is concerned with promoting the efficient domestic use of all solid fuels. In existing or proposed smoke control areas the Council's policy is aimed at the retention of the domestic market for solid fuel, either by the smokeless burning of coal, where this is possible—for example by means of mechanical stokers in blocks of flats, offices, etc.—or otherwise by the domestic use of smokeless solid fuels.

The Memorandum on Smoke Control Areas, published by the Ministry of Housing and Local Government in connection with the Clean Air Act, quotes the C.U.C. as one of the organizations from which local authorities, contemplating the establishment of Smoke Control Areas, may obtain advice and assistance.

The exhibit explains the ways in which the Council can be of service to Local Authorities that are setting up Smoke Control Areas, under the following headings:

Publications: The various publications issued by the Council which are available to local authorities are displayed. These include the List of Approved Domestic Solid Fuel Appliances (published jointly with the Solid Smokeless Fuels Federation) from which solid fuel burning appliances for replacement in Smoke Control Areas must be chosen.

Training Courses: The Ministry of Housing and Local Government Memorandum on Smoke Control Areas says that local authorities should ensure that new solid fuel appliances have been correctly installed in accordance with the methods recommended by the Coal Utilization Council.

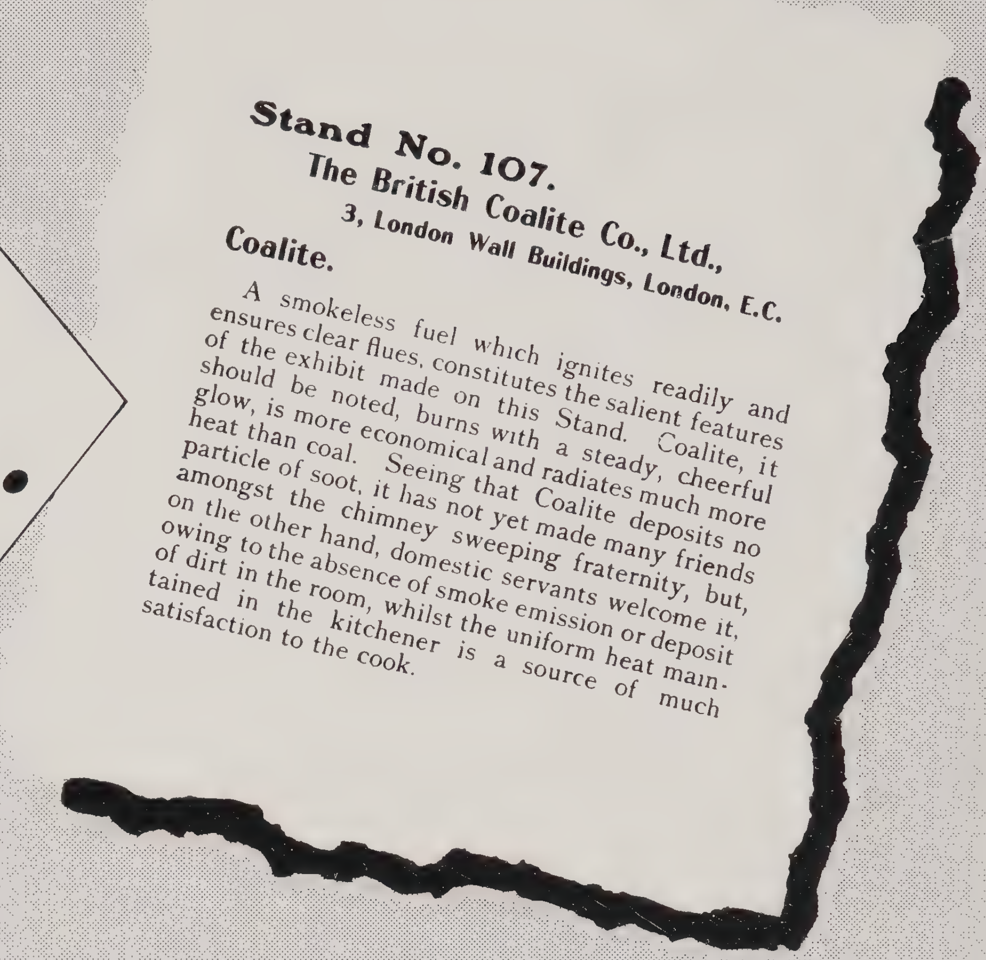
The training courses which the Council holds for builders, appliance distributors, and which are available to public health inspectors and other local government officers are described.

Exhibitions and Publicity: The stand illustrates the various ways in which the Council with its manifold resources, is able to help local authorities in proposed Smoke Control Areas by means of exhibitions of various types, adapted to suit local conditions, advertising and leaflets.

Technical Services: The technical services of the Council are available to any local

Extract from the catalogue of the International Exhibition organized by the Coal Smoke Abatement Society in

1912 . .



Stand No. 107.

The British Coalite Co., Ltd.,

3, London Wall Buildings, London, E.C.

Coalite.

A smokeless fuel which ignites readily and ensures clear flues, constitutes the salient features of the exhibit made on this Stand. Coalite, it should be noted, burns with a steady, cheerful glow, is more economical and radiates much more heat than coal. Seeing that Coalite deposits no particle of soot, it has not yet made many friends amongst the chimney sweeping fraternity, but, on the other hand, domestic servants welcome it, owing to the absence of smoke emission or deposit of dirt in the room, whilst the uniform heat maintained in the kitchener is a source of much satisfaction to the cook.

FIRST —AND STILL FOREMOST!

'COALITE'

SMOKELESS COAL

'Coalite' smokeless coal, the first successful smokeless solid fuel to be marketed in Great Britain is still the leader in its field. Economic, highly efficient, 'Coalite' is the ideal fuel for all domestic fires.

This year we are on

STAND 29

Come along and see a live 'Coalite' fire for yourself.

COALITE & CHEMICAL PRODUCTS LTD., CHESTERFIELD, DERBYSHIRE authority in connection with the domestic use of solid fuel in Smoke Control Areas, and technical officers of the Council will be on duty on the stand.

29 **COALITE AND CHEMICAL PRODUCTS LIMITED, P.O. Box No. 21, Chesterfield, Derbyshire**

Coalite and Chemical Products Limited, the producers of the popular "Coalite" Smokeless Coal welcome friends both old and new.

A live "Coalite" fire can be seen on the stand. Large "Coalite" is the ideal smokeless fuel for every type of domestic grate, old or new, and openable or closeable stoves. Cooker "Coalite", a smaller size, is equally suitable for cookers, openable or closeable stoves and hot water boilers.

"Coalite", which is very reactive, will laze or blaze according to requirements. It may be allowed to laze throughout the night or on other occasions when not required but will draw up to a cheerful blaze immediately the air regulator is opened.

"Coalite" is readily ignited in the ordinary way with paper and sticks, fire lighter or gas poker and burns cheerfully with flame giving radiant heat, maximum comfort and economy.

"Coalite" is equally as suitable as best house coal for the open fire and can be obtained from all leading coal merchants.

Prices vary throughout the country according to the geographical position in relation to the works and carriage charges that are involved. It is sometimes said that "Coalite" is expensive and whilst it may be true when this is considered initially in terms of shillings per hundredweight, the important point is that one buys by weight and consumes by volume. As "Coalite", all of which burns away without risk of flying pieces, is of greater volume than coal, it is cheapest in the long run.

It is most important to note that "Coalite" will burn satisfactorily in any type of grate or appliance without the expense of alteration.

5 **THE COLLEGE OF FUEL TECHNOLOGY, Highgate, N.6 (The Clean Air Information Service)**

Supposing a local authority was to appoint a professionally qualified staff of scientists, engineers and fuel technologists with the experience needed effectively to tackle the amazing variety of scientific, engineering and fuel burning problems with which the implementation of the Clean Air Act is beset. Such an authority would have a staff closely akin to the staff and instructors of The College of Fuel Technology, the majority of whom also have the further qualification that they are actually concerned professionally with these specific problems within industry.

The tutorial staff and instructors of the College include:

Doctors of Science
A Chemical Engineer
Research workers engaged on fuel problems
A Civil Engineer
Mechanical Engineers
Fuel Technologists and Plant Engineers

This body of men and experience lies behind the Clean Air Information Service, and because this is so, and the College is a non-profit making foundation with the necessary establishment, any local authority may be served by this organization for an annual contribution which is a fraction of the wages of a dustman.

The service operates through codes of practice which provide routines by which local Clean Air Information Services can draw freely upon the services of this "backroom" staff. And in order that this shall remain so, questionnaires and information sheets provided for local use are overprinted with "The Public Health Department" of the appropriate borough.

The display is designed to show how this service operates and the ways in which it can benefit local authorities participating in it.

Stand No.

1 **EDWIN DANKS & COMPANY (OLDBURY) LIMITED, Oldbury, near Birmingham**

With nearly a century of service to industry in progressive boiler construction, Edwin Danks of Oldbury are happy to be associated with the Diamond Jubilee of the National Society for Clean Air. During the past hundred years Edwin Danks have initiated many of the advances in industrial steam-raising efficiency; not least, in the development of the Oldbury Chain Grate Stoker and the new "Airspin" Rotary Cup Oil Burner, two major contributors to efficient combustion and the cause of clean air.

Some fourteen years before the passing of the Clean Air Act, the universally known Oldbury Stoker, the first successful chain grate unit for shell boilers, proved its ability to burn the widest range of solid fuels, graded and ungraded, efficiently and smokelessly. Today, in nearly 6,000 installations the Oldbury Stoker burns almost every type of solid fuel to comply with the strictest requirements of the Act —Ringelmann 0, in fact—and maintains full boiler makers' ratings.

Edwin Danks "Airspin" Rotary Cup Oil Burner, also specifically designed for shell type boilers, is of extremely simple design. This very modern product of the Edwin Danks Combustion Division provides optimum efficiency in atomization, easy maintenance, high availability, and, of course, effective, smokeless combustion. It is supplied semi or fully automatic or hand controlled.

The burner exhibited is the fully automatic type, suitable for burning all grades of industrial fuel oil.

38 **DISTRICT BANK LIMITED, Head Office: Spring Gardens, Manchester 2**

37 **DRUMMOND PATENTS LIMITED, 5 Great Winchester Street, London Wall, London, E.C.2**

A working model of a Drummond Washer Filter shows the fan, which is the only moving part, drawing air through the washer and creating a double wave and heavy spray. The air undergoes a very intense scrubbing, although there is no great increase in humidity. Large and small particles are trapped in the water and gradually settle to the bottom if they are heavier than water, or are bled off if they are lighter than water. The filter is therefore always working in the same condition and the air through-put remains the same.

The principle has been used for over twenty years in dealing with dust and fumes from boilers, furnaces, cupolas, convertors, coke and coal handling, shot blasting, foundries, grinding, polishing plating and both paint manufacture and spray painting. It has been made in sizes up to 125,000 cu. ft. per min., catching up to 6 tons of dust per day.

35 and 36 **DUNEDIN ENGINEERING CO. LTD., 73-75 Mortimer Street, London, W.1**

The new Dunedin System for direct application to running diesel engines has been developed to fulfil an ideal long recognized by diesel engineers.

Among its advantages and functions is ability in service to ensure the elimination of diesel engine smoke.

Irrespective of the type of diesel engine, whether mobile or stationary, be it low, medium or high speed, the Dunedin principle is one which can effectively be introduced either for workshop or field service, its easy portability being a handy feature.

In practice, the Dunedin System has revealed that when diesel engines which emit black smoke are tested, the injection pressure is invariably from 15 to 30 atmospheres low. When this condition is corrected and the injectors are properly balanced to the fuel pump as the Dunedin System ensures, the smoke in 90 per cent. of cases is eliminated. The exceptions to this are when the cause is excessive over-calibration of the fuel pump but, even so, very considerable reduction of smoke can be effected.

The instruments which form the basis of this new maintenance technique are

THE BEST OF BOTH WORLDS

Consult Edwin Danks at Oldbury, on all combustion problems.

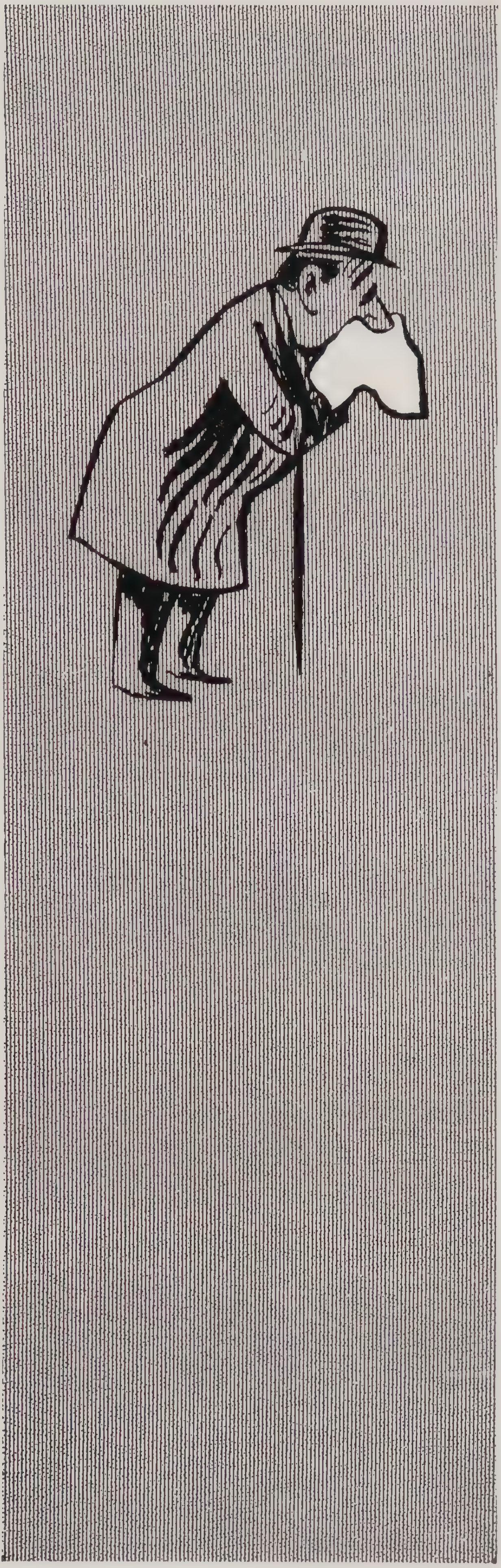
EDWIN DANKS & CO (OLDBURY) LTD

A Comprehensive
Steam-Raising Service from
EDWIN DANKS
COMBUSTION DIVISION

Edwin Danks Modern Economic Boilers (High Velocity Double Pass, Treble Pass, Thermal Storage and Wet Back) fired by the new 'Airspin' Turbine-Driven Rotary Cup Oil Burner *or* the universally known Oldbury Chain Grate Stoker.
Edwin Danks New 'Airspin' Oil Burner and the Oldbury Stoker were specifically designed for shell-type boilers.

Both guarantee smokeless operation to comply fully with the Clean Air Act.

OLDBURY, NEAR BIRMINGHAM
TEL: BROADWELL 2531



Electricity clears the air

Housing, industry and railways are turning to electric heat and power. And tomorrow, thanks to nuclear power stations, expanded electricity supplies will help to eliminate even more sources of visible or invisible pollution. Electricity—for health's sake!

Come and see how Electricity clears the air at STAND 8-9

Issued by the
Electrical Development Association,
2 Savoy Hill, London, W.C.2.

simple to understand, easy to apply and to read, no special training being necessary, no complicated adjustments are required and personal judgement is eliminated.

Their use provides not only a certain remedy for the main causes of excessive smoke but, in addition, establish increased b.h.p. and reduced fuel consumption, together with considerable time saved in the process.

The following represent the complete range of equipment concerned:

Injectester. Checks and adjusts injectors, and tests delivery valve seats and plungers under operating conditions of temperature, pressure, volume and fuel, resulting in perfect balance between injector and fuel pump.

Diestester. Records engine compression in medium and high speed engines at running speed. The ideal complement to the Injectester.

Injectometer. Carries out all tests applicable to the Injectester except plunger test.

Diesindicator. Registers peak and initial firing pressures of low, medium and high speed engines wherever there is access to the combustion chamber. Operates for 75-100 separate tests without need for cleaning or other maintenance.

8 and 9 ELECTRICAL DEVELOPMENT ASSOCIATION, 2 Savoy Hill, London, W.C.2

This exhibit features displays which illustrate the tremendous contribution electricity is making towards the achievement of clearer skies and healthier Britain.

Visitors to the stand will see how electricity, made even more plentiful by the advent of nuclear energy, provides clean low cost light, heat and power for homes and factories and how older buildings can be brought up to date with specially designed electrical apparatus. Of special interest to those concerned with the design and development of new buildings is the section which shows how electric under floor heating combines the advantages of low installation costs with efficiency and economy in operation.

E.D.A. publications, including "Nuclear Power to Clear the Air", "The Clean Air Act and You" and the synopsis of the film "The Future is Electric", are freely available from the E.D.A. exhibit where a friendly and experienced staff is ready to advise on equipment and answer questions relating to electrical installations elegible for grants under the Clean Air Act.

3 and 4 THE GAS COUNCIL, 1 Grosvenor Place, London, S.W.1

During its 150 years' history, the gas industry has made a substantial contribution to the ideal of clean air by producing on an ever-increasing scale the two smokeless fuels, gas and coke, and by offering, freely, technical advice on their most efficient use in home and factory. Today, the industry is one of the most active workers in the drive to achieve the objects of the Clean Air Act.

Replacing smoky fires. It is well-known, of course, that the domestic chimney is responsible for nearly half of the smoke that is daily poured into the air. Visitors to the Gas Council's stand will, therefore, be specially interested to see how easily and efficiently old-fashioned fireplaces originally designed to burn smoky coal, can be replaced by modern approved gas or coke-burning appliances which combine both convected and radiant heat, and so ensure greater comfort and economy, as well as cleaner air. But the clean, smoke-free efficiency of gas make it by far the best fuel to use for *all* essential domestic fuel services: cooking, water heating, refrigeration and home laundering. Gas looks after family comfort and well-being as no other fuel can.

Gas in shop and factory. Gas is equally useful in shop and factory, especially now that the provisions of the Clean Air Act affecting the control of dark smoke are binding. Gas is used in over 4,000 industrial processes where flexibility and accurate control of temperature are essential. It is also invaluable for space heating and water heating on a large scale. Coke is an economical alternative fuel for this purpose.

Gas and coke between them put paid to "Guilty Chimneys"!

Stand No.

10 and 11 **THE GENERAL ELECTRIC COMPANY, Magnet House, Kingsway, London, W.C.2**

Many recent introductions in space heating equipment are featured. These include the latest addition to the popular range of Nightstor heaters, the 1 kW low level model.

Shown for the first time are the G.E.C. 1½ kW and 3 kW, twin-zone radiant heaters which can be adjusted easily to either narrow or broad beam positions for localized or dispersed heating. A new 10 kW low level fan heater is shown in addition to the well-known 3 kW wall and floor mounting heaters.

Examples of the recently introduced hot water circulators for use with central heating systems, available in loadings from 12 kW to 108 kW, are shown as well as a fifty-gallon storage water heater. All the equipment complies with the requirements of the Clean Air Act.

Other industrial equipment includes a working example of the Company's latest smoke density recording equipment. A visible light beam is projected across the path of the flue gases in the stack, and variation in luminous intensity owing to smoke density is measured by a photo-electric cell and associated amplifier. The loss in transmission of light through the gases is displayed as "percentage obscuration" on suitable recording devices. The highly accurate apparatus consists of: projector, receiver and control box, along with a wide choice of recording and indicating units.

Fires and heating appliances for the home include the Cosyglo fire. The design of the reflector is exclusive to G.E.C. and really does give all-round warmth.

13 **JAMES GORDON & CO. LTD., Dalston Gardens, Stanmore, Middlesex**

A selection of boiler efficiency instruments from the complete range of instrumentation and automatic control offered by Gordons and which is suitable for any type or size of boiler plant.

The instruments displayed will include the Mono chemical type CO_2 Recorder and Mono Portable CO_2 Tester, the Elliott thermal conductivity type CO_2 analyser with indicators and recorder, steam meters, temperature indicators and recorders, and the new Konitest dust metering equipment for measuring the dust burden of boiler exit gases and industrial atmospheres.

33 **W. C. HOLMES & CO. LTD.,**
Turnbridge, Huddersfield

Holmes-Schneible Multi-Wash System

The Holmes-Schneible Multi-Wash System is applicable to a wide range of dust collection and control problems involving liquid and solid particles. The multi-wash collector has many advantages over other types of collectors—it has an extremely high efficiency (of the order of 99 per cent. for all particles above 3-4 microns); it has a lower pressure drop than many other types of wet washers, and an absence of circuit restrictions which might cause blockages.

Built into the multi-wash collector are three established methods of dust collection:

1. The tangential entry of the gases into the circular base of the collector utilizes centrifugal force to throw out the heavier particles.
2. The dust particles are bombarded by a fine divided self-induced water spray.
3. The dirty gases pass over large wetted areas.

Each multi-wash collector consists of a varying number of impingement or washing stages depending on the efficiency required. Each impingement stage consists of a number of mild steel turbine-like blades welded to a shallow cone. These impingement stages are arranged within the collector, the lower portion of which is formed into a conical hopper to drain off the mixture of water and dust.

The dust-laden air enters the collector tangentially immediately above the coned portion and travels upwards with a spiral motion through each impingement stage until it reaches the clean air outlet at the top of the collector. The water is admitted through an open bore pipe, at no head pressure, and forms a water curtain at each impingement stage. On meeting the air current, the water is broken up into a fine spray which impinges on the particles of dust causing them to be directed towards the periphery of the collector and subsequently washed downwards towards the sludge drain. In order to prevent water carry-over to the fan, an entrainment separator, similar in construction to an impingement stage is fitted immediately above the water inlet pipe.

Holmes-Rothemuhle Multi-cell Cyclone Dust Collector

This collector has been designed to minimize grit emissions from hand, stoker and pulverized fuel-fired boilers. The Holmes-Rothemuhle Collector is an inexpensive and efficient solution to many of the problems involved in the collection of dust and grit particles in the higher size ranges (particle sizes in excess of 10 microns.)

The multi-cell cyclone is the cheapest and simplest type of mechanical dust collector and is suitable for a variety of problems ranging from the removal of fly-ash from boiler flue gases to the recovery of valuable dust and fines from crushing, grinding and drying operations.

34 **LANCASHIRE DYNAMO ELECTRONIC PRODUCTS LTD., Rugeley, Staffordshire**

The Lancashire Dynamo stand will feature a display of electronic control equipment particularly associated with applications to ensure compliance with the provisions of the Clean Air Act.

Exhibits will include examples from the range of Smoke Densitometer and Alarm equipment and accessories, the first of its kind to carry the British Standards Institute's "Kite Mark" indicating independent certification of compliance with BS 2740/56 and, plus the appropriate indicating instrument, with BS 2811/57.

LODGE-COTTRELL LIMITED

This Company founded by the late Sir Oliver Lodge in 1913, specializes in Electrostatic Precipitation and has been constantly in the forefront throughout the British Commonwealth and also perhaps throughout the world. The principle of the system pioneered by Sir Oliver Lodge now forms the basis of all known forms of electric precipitation.

Precipitation is used largely for prevention of atmospheric pollution, but may be used for the collection of valuable dust or fumes from a process gas, and alternatively for the removal of impurities from a gas to render it suitable for commercial or industrial use.

Under one or other of these headings Lodge-Cottrell Plant is already installed for the removal of the following:

Dust and ash from boiler waste gases.
Impurities from Blast Furnace and producer gas, sinter strand gases and many others.
Alumina and cement dust from kiln gases.
Sulphuric acid mist.
Dust from basic slag crushing and grinding plant.
Coal dust from driers, grinders, etc.
Tin, copper, lead, silver, gold, selenium, etc., from smelting and refining.
Reduction of haze and removal of Sodium Hydroxide from Auto-diesel oil.

Other industries to whom our equipment has been supplied are numerous and include those producing carbon, paper, plaster, coal, etc.

The models exhibited are on a very small scale and this can be judged from the size of the stairways. Nevertheless, Lodge-Cottrell Limited manufacture electrofilters of almost every size from small to very large indeed. Each unit is designed for a particular job and specified efficiency and in consequence enquiries cannot properly be attended to unless full information is supplied. Questionnaires are available on the stand.

The Company is now backed by the financial resources of the Simon Engineering Group.

"Half the battle for clean air depends on good equipment, properly maintained. But victory in the battle rests in the hands of the Stoker".

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NEW STOKER'S MANUAL

— more than 10,000 copies already sold.

NOW ON SALE
PRICE 2/6d
POST FREE

N·I·F·E·S

TRAINING COURSE FOR BOILER OPERATORS

— is also available anywhere in the United Kingdom.

2,500 N.I.F.E.S trained men have obtained the City and Guilds Boiler Operator's Certificate.

*

N·I·F·E·S

National Industrial Fuel Efficiency Service

71 GROSVENOR STREET LONDON W1
TELEPHONE: HYDE PARK 9706

Stand No.

22 **MINISTRY OF HOUSING AND LOCAL GOVERNMENT,**
Whitehall, London, S.W.1

A large illuminated map shows the progress of smoke control in England and Wales. The map itself marks the "black" areas of air pollution, against the background of which coloured lights show both smoke control areas already in operation and those proposed. Smaller maps show the progress to date of the five-year smoke control programmes in two main "black" areas.

16 **MIRRLEES WATSON COMPANY LTD.,**
Kennerley Works, 163 Buxton Road, Stockport

On display is a sectioned Stoker gearbox with the working mechanism exposed. This shows the method by which several different rates of coal feed may be obtained, and also the manner in which a "breathing" action is imparted to the fuel bed by pulsating transmission, thereby ensuring intimate mixing of fuel and air which enables the Mirrlees Stoker to operate at high efficiency with a wide variety of coals.

A framed set of photographs show a few of the numerous types of application to which Mirrlees Automatic Underfeed Stokers have been successfully applied. Our Stoker installations include: Boilers (of all types), Furnaces, Kilns, Tar Stills, Whiskey Stills, Ladle Driers, Grass Driers, Stone Driers, Core and Mould Drying Stoves, Salt Pans, Air Heaters, Galvanizing Baths, Metal Melting Pots, etc.

A large coloured drawing shows in section a typical installation in a vertical steam boiler.

A selection of literature is available giving details of our Hopper and Bunkerfed Stokers, Coke Stokers and Forced Draught Burners.

27 **THE NATIONAL CARBONISING COMPANY LTD.,**
Thorney House, Smith Square, London, S.W.1

The National Carbonising Company Ltd. of Mansfield, Nottinghamshire, one of the pioneers of domestic smokeless fuel, is exhibiting its Rexco products and also giving a burning demonstration in a Redfyre convector hearth.

The convector fire being shown is typical of those now being installed throughout the country to comply with clean air regulations.

Rexco smokeless coal made from best quality washed large coal with an ash content of 4 per cent, is the ideal fuel for all open hearth fires, boilers and both open and closed stoves. It is one of only two smokeless fuels that can be easily lit with just sticks and paper.

This particular smokeless coal offers many advantages over ordinary untreated coal and can be used without altering existing stoves or grates. It is clean and light to handle, will now easily break up, lights quickly, is economical to use and emits much greater heat than coal.

Supplies of Rexco have until now been strictly limited, but this winter will be doubled by the introduction of another carbonizing plant at Edwinstowe, Notts.

This modern fuel is available in sizes to meet all household requirements. Large Rexco is for open fires; Rexco Nuts for stoves, boilers and cooking ranges; and Rexco Beans for small boilers. Also available to meet the demand of industry in smokeless zones, the National Carbonising Company offers Rexco Beans and Breeze.

Rexco Beans are specially recommended by Newton Chambers Ltd. of Sheffield, makers of the Emma Boiler, a model of which is displayed on the stand, and also by the Hemel Hempstead Engineering Company Ltd. for their Suxe Boiler.

Samples of each grade of Rexco smokeless fuel are available on this stand.

32 **NATIONAL INDUSTRIAL FUEL EFFICIENCY SERVICE,**
71 Grosvenor Street, London, S.W.1

Pictorial Panels illustrate how N.I.F.E.S. Services can help both local authorities and industry in their fight for clean air.

A Regular Service Agreement with N.I.F.E.S. ensures that equipment is properly maintained and correctly operated. By means of the Specific Advisory Service a remedy can usually be found for smoke and grit problems. N.I.F.E.S. Boiler Operator Training Course prepares stokers in theory and practice for the Standard qualification of the City and Guilds Boiler Operator's Certificate. Technical advice is also available to local authorities when they are considering applications for prior approval of new equipment.

The new *Stoker's Manual*—the handy pocket size reference book for the stoker—recently published by N.I.F.E.S. will be available on the Stand.

39 **NATIONAL SOCIETY FOR CLEAN AIR, Palace Chambers, Bridge Street, London, S.W.1**

The Society's stand features a colourful display of posters for Clean Air and a series of photographic panels, entitled "Air Pollution and the Photographer", chosen from the Society's photographic library of well over 1,000 prints.

The posters include prize winners and others chosen for publication from over 500 entries received for the Clean Air National Poster Competition which the Society organized jointly with the *News Chronicle* last winter. Throughout the competition the special needs of local authorities in respect of publicity for the implementation of the Clean Air Act were borne in mind, and each poster was selected to fulfil a specific requirement in the campaign for cleaner air. Orders for the posters will be welcomed at the Society's bookstall in the foyer.

The photographic panels are those prepared for display on the new portable display units available for loan by local authorities. Details of the loan of the photographic panels and illustrated leaflets on the portable display units can also be obtained from the Society's bookstall.

31 **PRAT-DANIELS (STROUD) LTD.,**
Whitecroft, Nailsworth, Stroud, Glocuestershire

On the Stand will be models of various types of dust collecting equipment including the Wet Type Spark Arrester for Foundry Cupolas, the High Efficiency Tubular Dust Collector, the Prat-Daniels Turbocollector and Low Resistance Dust Collector for Industrial Boiler Plant.

23 and SHELL-MEX AND B.P. LTD.,
28 Shell-Mex House, Strand, London, W.C.2

The clean combustion of oil fuel is demonstrated in a live boiler exhibit on the stand of Shell-Mex and B.P. Ltd. The use of the Shell Smoke Meter, and the very high standards of combustion set and achieved by the Oil Industry are shown.

Chimney dimensions set local authorities many problems, and the information on chimneys for oil fired equipment which Shell-Mex and B.P. present on their stand will be of great interest to delegates.

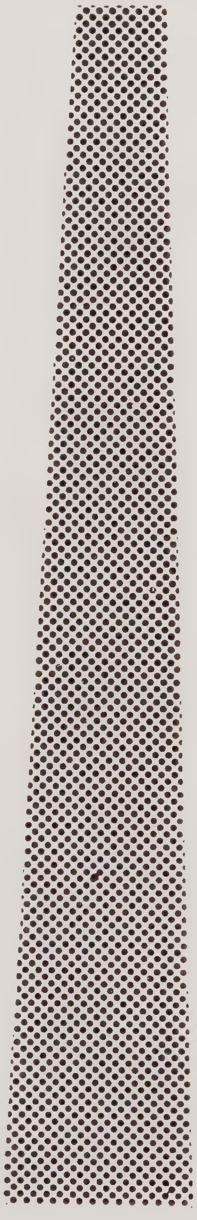
14 and SIMON-CARVES LIMITED,
15 Cheadle Heath, Stockport

Simon-Carves Ltd. have made electro-precipitation one of their specialities for over 30 years. They have installed many hundreds of precipitators ranging from modest de-tarrers and de-misters, to flue-dust precipitators of comparatively massive proportions. This wealth of experience has led to the Company being entrusted with the precipitator contract for the largest single boiler unit in the world, at Thorpe Marsh Power Station. Recently they commissioned the first open-hearth furnace precipitator in the United Kingdom.

Precipitators are often criticized for their capital cost; their low operational cost is conveniently forgotten. Simon-Carves precipitators usually add only about 0·25″ w.g. to the fan power. Alternative methods of comparable efficiency add from

Power Stations and Clean Air

CEGB



Keeping the air clean is important to the Central Electricity Generating Board, not only because it is desirable in itself but because it actually saves fuel—smoke represents unburnt carbon which is in turn lost energy.

But, with the high ash content of the coal the Generating Board use, dust inevitably passes through into the flue ducts. The removal of this dust is regarded as so important by the Generating Board that they spend up to half-a-million pounds at every new coal-fired power station on electrostatic precipitators which trap all but one per cent of the solids.

Even then there are the gases themselves to consider. The tall chimney stacks of power stations throw these gases into the upper atmosphere where they disperse harmlessly.

From nuclear stations there will of course be no chimney emission whatsoever.

The Central Electricity Generating Board are doing everything they can for clean air.

Issued by the Central Electricity Generating Board

4″ to 12″ w.g. resulting in additional fan-power costs from 20 to 60 times as great.

Rapid scientific development in recent years has created many new and challenging problems in this field. It is here that the vast technical resources and research facilities of the Simon Group, and its contact with so many different industries, are unique.

The Company's recent acquisition of Lodge-Cottrell Ltd., the pioneer precipitation Company in Great Britain, with the resultant pooling of knowledge, will lead to better plants with increased efficiency, and will be of great importance in providing the answer to many of the air pollution problems requiring treatment under the Alkali Act, Clean Air Act, etc.

Our exhibits illustrate the Fulham-Simon-Carves Process for the removal and recovery of sulphur from stack gases. This consists essentially of scrubbing the flue gases with ammonia liquor to produce a solution of ammonium salts which by autoclaving are then converted into ammonium sulphate and sulphur.

The economics depend upon the size of installation and the percentage of sulphur in the fuel, but where the gases from large tonnages of high sulphur fuels are being treated, estimates show that the process can be operated at a profit.

25 and 26 SOLID SMOKELESS FUELS ASSOCIATION,
74 Grosvenor Street, London, W.1

The Solid Smokeless Fuels Federation stand shows solid smokeless fuels actually burning and demonstrates the heat output from these fuels in the modern approved appliance.

A map is also displayed showing the overall position in the country in regard to the smoke control areas in operation and proposed up to the 31st August.

A full range of solid smokeless fuels approved for use in smoke control areas is also displayed.

18 STURTEVANT ENGINEERING CO. LTD.,
Southern House, Cannon Street, London, E.C.4

As pioneers in the movement of air in industry, the Sturtevant Engineering Co. recognized many years ago that conditions would arise as a result of industrial developments, which would necessitate the large scale filtration of effluent gases from large boiler installations, etc., and the air in and around certain types of works. Accordingly, research work and testing of various devices for collecting grit and dust, from comparatively coarse particles to those in the sub-micron range, has resulted in the production by this Company of practically every known type of dust arrester.

Sturtevant Electrostatic Precipitators for cleaning industrial gases emanating from power stations, cement works, metallurgical and chemical works, etc., are in operation all over the world; many similar to that shown in the model being in this country. Efficiencies of dust arrestment up to 99·7 per cent have been recorded.

Precipitron Electrostatic Air Filters similar to the unit exhibited are treating millions of cubic feet of air per minute, for the removal of particulate matter, in factories, offices, laboratories, etc.

Sturtevant "Fleetway" Paper Filters may be used alone or in conjunction with Precipitron for the complete filtration of air, removing all particles down to 0·01 micron. A unit is exhibited.

The Sturtevant Newgate Collector is designed to arrest the comparatively coarse grits emitted by small and medium-sized boilers. It incorporates a heavy duty fan, inlet box, primary collector and secondary cyclone with a special cyclone booster trunk unit to generate the differential pressure required to drive the concentrates through the cyclone unit. A model of the arrangement is shown.

The Sturtevant "Ludgate" Low-Loss Mechanical Dust Collector is ideal for use alone in any boiler flue system or as a pre-collector which gives good dust-arresting efficiencies over a wide range of operating conditions.

Sturtevant High Efficiency Cyclones are designed on fundamental aerodynamic

CLEAN AIR WITH STURTEVANT PLANT

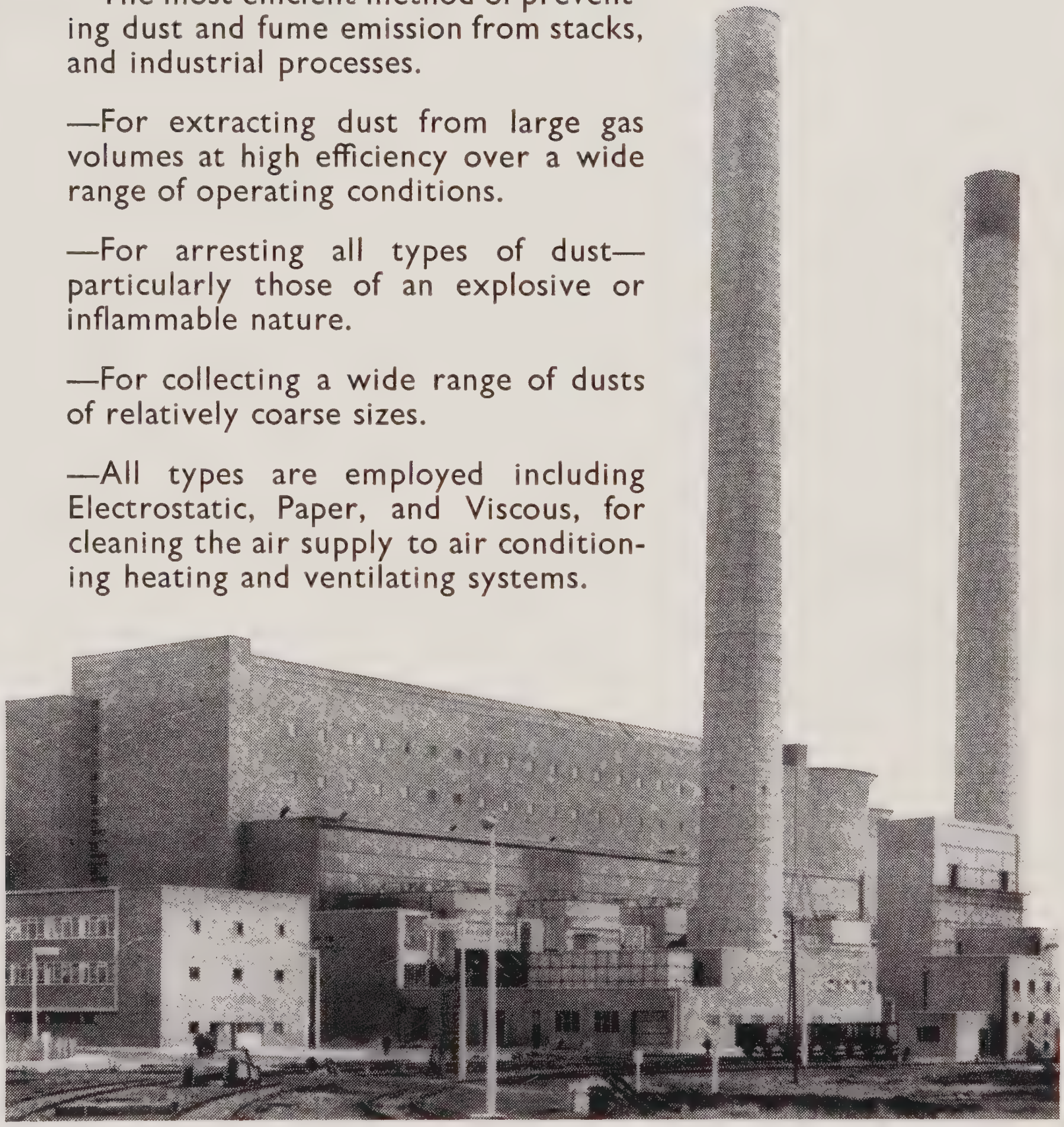
ELECTROSTATIC PRECIPITATORS —The most efficient method of preventing dust and fume emission from stacks, and industrial processes.

MECHANICAL DUST COLLECTORS —For extracting dust from large gas volumes at high efficiency over a wide range of operating conditions.

SCRUBBERS —For arresting all types of dust—particularly those of an explosive or inflammable nature.

CYCLONES —For collecting a wide range of dusts of relatively coarse sizes.

AIR FILTERS —All types are employed including Electrostatic, Paper, and Viscous, for cleaning the air supply to air conditioning heating and ventilating systems.



Sturtevant Precipitators are installed at Goldington Power Station

For further particulars of any of this range of plant write to our reference Z/101/LM.

STURTEVANT ENGINEERING CO. LTD.
Southern House, Cannon Street, London, E.C.4

AUSTRALIA: STURTEVANT ENGINEERING CO. (AUSTRALASIA) LTD. 400 SUSSEX STREET SYDNEY N.S.W.

principles, and yield remarkably high dust-collecting efficiencies.

Sturtevant Scrubbers are available in several types for the wet arresting of inflammable or explosive dusts.

Sturtevant plant is cleaning many millions of cubic feet of air every minute: it has done so for many years and will continue to do so, for Sturtevant and Clean Air are synonymous terms.

2 **JOHN D. TROUP LTD.,**
90 High Holborn, London, W.C.1

Troup Publications are designed to assist operating engineers to achieve higher operating efficiencies, and to meet the requirements of the Clean Air Act.

The Steam Engineer is the monthly journal for engineers responsible for steam and power generation and utilization in all industrial plants and power stations. Annual subscription 30/- post free.

Heating, also published monthly, covers all aspects of the heating, ventilating and air conditioning of industrial, commercial and domestic premises, including public buildings. Annual subscription 25/- post free.

A comprehensive range of booklets and charts are also published, including the well-known Boiler Maintenance Chart and Fuel Saving Charts. Important subjects covered by the booklets include boiler testing, the operation of heating boilers, the economic use of fuel oils for steam raising and central heating, structural insulation, off-peak electric space heating, and defects and repairs of all types of boiler.

30 **WARREN SPRING LABORATORY OF THE DEPARTMENT OF SCIENTIFIC INDUSTRIAL RESEARCH (Atmospheric Pollution Division)**

Local authorities and other organizations have collaborated with the Department of Scientific and Industrial Research in the measurement of atmospheric pollution for many years and the data obtained have now been built up into a body of evidence of considerable statistical significance. A start is now being made on a thorough examination of this material and the present exhibit explains a few of the first tentative results. They are concerned with the changing pattern of pollution during the last six years and with the distribution of smoke throughout the country.

It should be noted that the Atmospheric Pollution Division of the Warren Spring Laboratory will be moved to the main Laboratory at Stevenage at the end of this year.

17 **THE WOMEN'S ADVISORY COUNCIL ON SOLID FUEL,**
18 South Molton Street, London, W.1

The Women's Advisory Council on Solid Fuel has designed its stand to draw attention to the service which the Council can give to local authorities setting up Smoke Control Areas.

The Council's fifteen Regional Organizers are available to address women's meetings, and they support their talks with filmstrips and coloured slides. They are also ready to demonstrate to householders the operation of new solid fuel burning appliances, and to explain how solid smokeless fuels can be used to the best advantage.

The Council's London Regional and Southern Regional Organizers, Miss D. Hankey and Miss V. E. Hollands, will be in attendance to answer enquiries.

THE
MUNICIPAL JOURNAL

and

Municipal Engineering

Recognised
as *the* weekly authorities on *Clean Air*

3/4 CLEMENTS INN, W.C.2.
HOLborn 2827 and 5502

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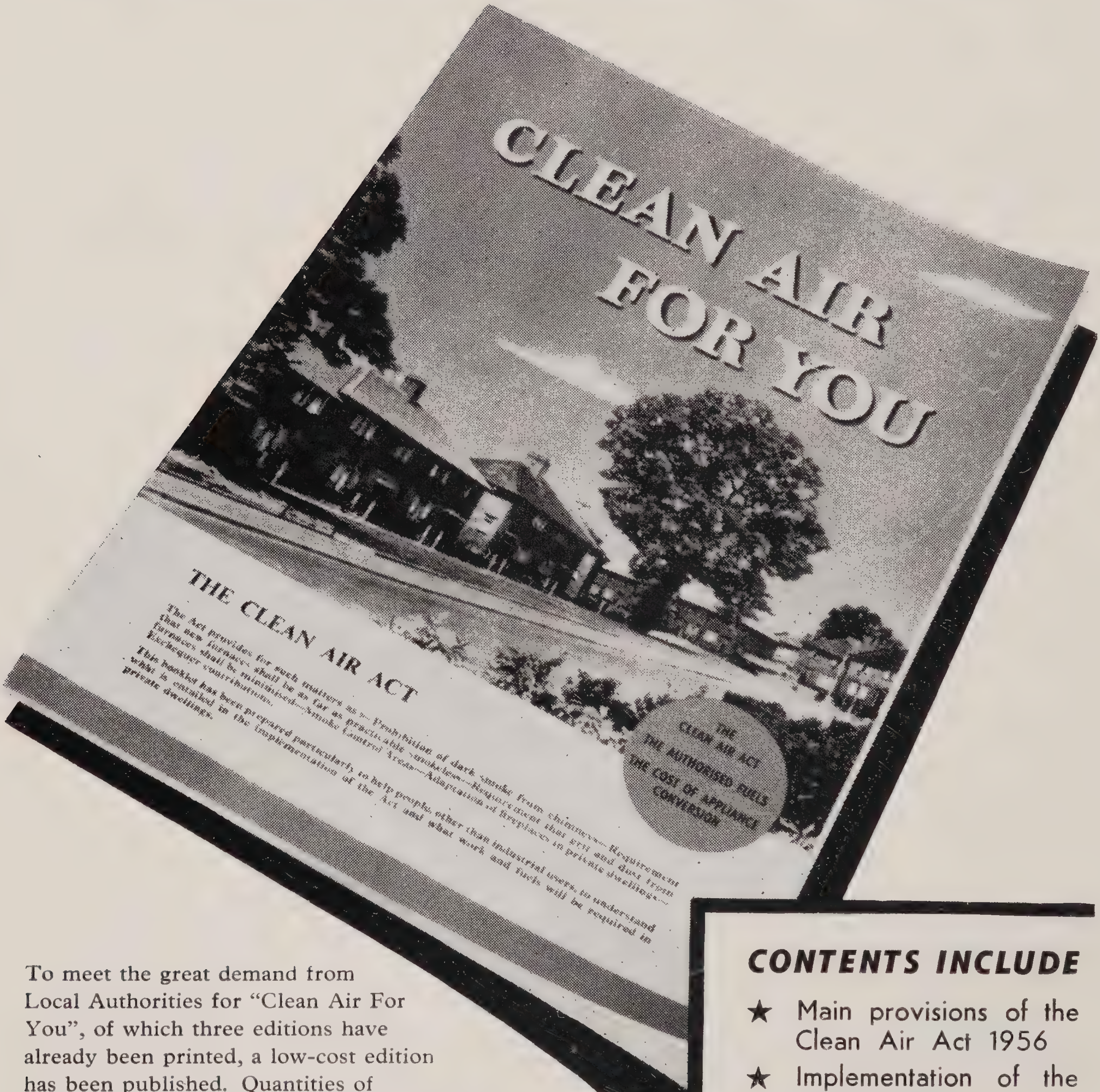


CLEAN AIR FOR YOU

THE CLEAN AIR ACT

THE CLEAN AIR ACT
THE AUTHORISED FUELS
THE COST OF APPLIANCE CONVERSION

To meet the great demand from Local Authorities for "Clean Air For You", of which three editions have already been printed, a low-cost edition has been published. Quantities of this authoritative publication can be supplied to meet any requirements. Specimen copies and terms for supplies can be obtained on application to the Solid Smokeless Fuels Federation.

CONTENTS INCLUDE

- ★ Main provisions of the Clean Air Act 1956
- ★ Implementation of the requirements.
- ★ The Authorised Fuels
- ★ Modifications and Replacements.

(with a full range of illustrated examples giving estimated COSTS)

S.34

SOLID SMOKELESS FUELS FEDERATION · **74 Grosvenor Street, London, W.1.** *MAYfair 3327*

The National Coal Board are contributing towards Clean Air by developing the production of smokeless fuels such as Anthracite, 'Phurnacite', Hard Coke, 'Warmco' and the new processed fuels still in the laboratory stage, and by promoting the more enlightened use of bituminous coal in modern plant and appliances.

THE NATIONAL COAL BOARD

The boiler doesn't smoke

(and the owner doesn't stoke!)

Back in the dark days you stoked the boiler high, and and you kept the fire low. But the smoke went up the chimney just the same. You pushed the damper in, and you pulled the damper out. But the smoke went up the chimney just the same. Maddening!

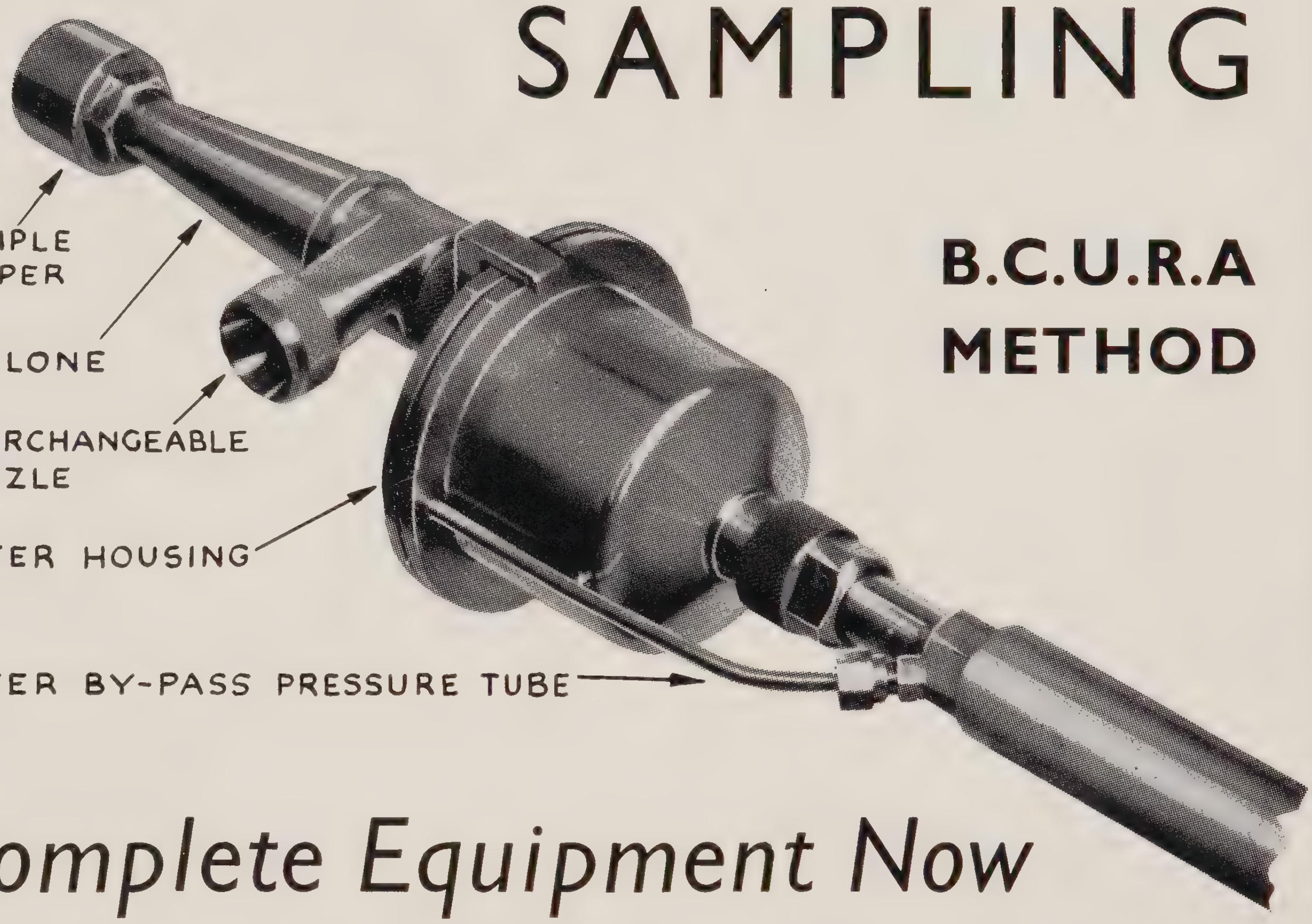
But times change. And so, happily, do boilers. A 'Potterton' Boiler gives central heating *automatically*. The boiler doesn't smoke, and the owner doesn't stoke, because every 'Potterton' Boiler, be it gas-fired or oil-fired, is a model of smokeless, stokeless efficiency.

Fortunately, there's a 'Potterton' Boiler to suit everyone, from the householder to the industrialist. Why not ask the 'Potterton' people for full information and running costs? They'll gladly send them to you—or answer any questions you might have. The address is Thomas Potterton Ltd., 20/30 Buckhold Road, London S.W.18; the telephone number, VANdyke 7202.

PT1005A

FLUE GAS DUST
SAMPLING

B.C.U.R.A
METHOD



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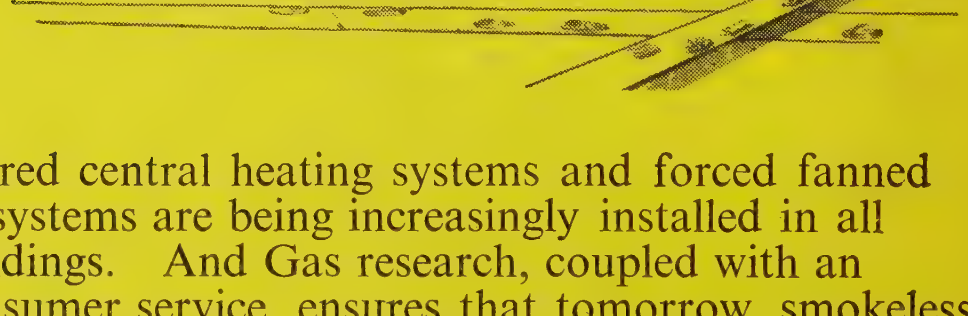

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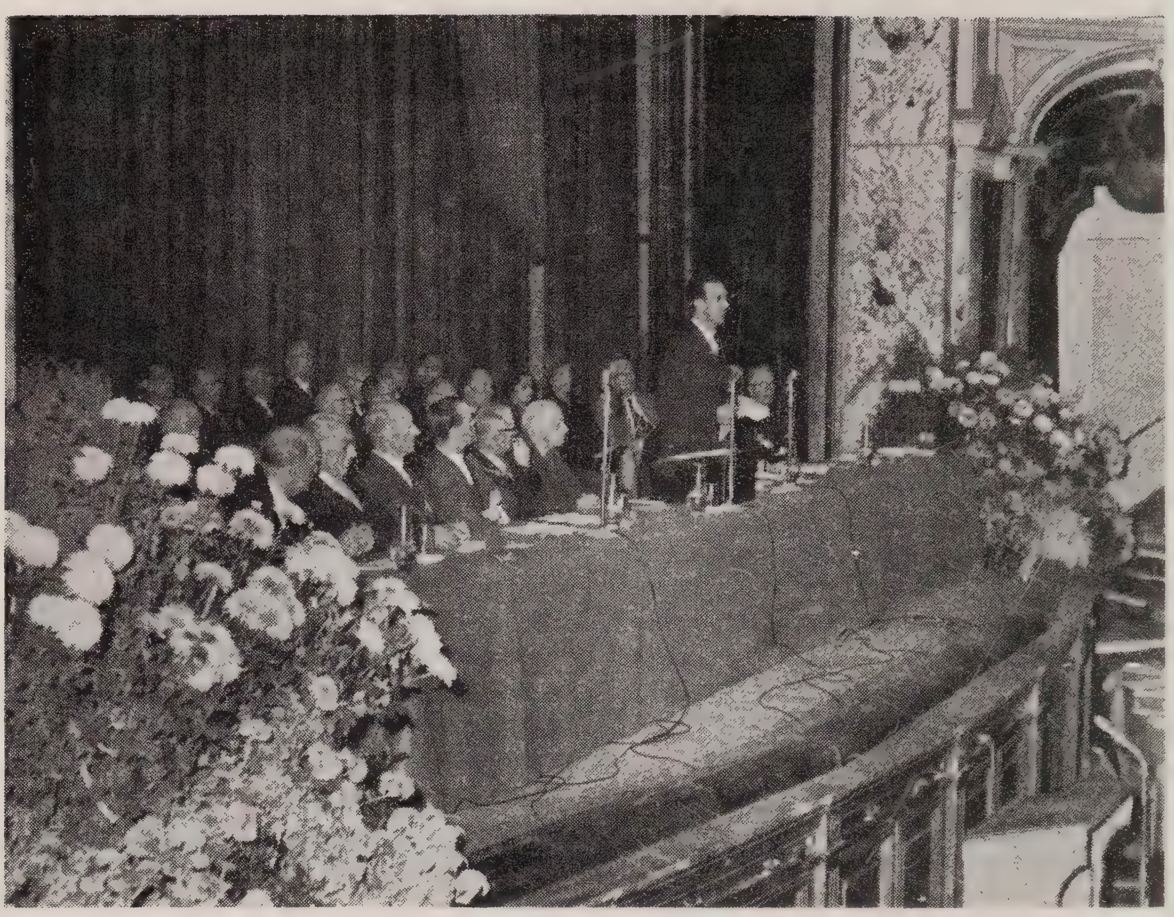

Sir Keith Joseph, M.P., Parliamentary Secretary, Ministry of Housing and Local Government, addressing the conference at the opening session

CONTENTS

Index to Authors and Speakers 5

Summary of Events 6

Session I

Address by Sir Keith Joseph, M.P., Parliamentary Secretary, Ministry of Housing and Local Government 7

Presidential Address by Sir Hugh Beaver, K.B.E. 11

Session II—Air Pollution from Road Vehicles

The Administrative Control of Smoke from Road Vehicles, by D. Lister .. 17

Prevention of Air Pollution by Diesel-Engined Road Vehicles, by G. J. Waring 25

Methods of Removing Smoke from the Exhausts of Diesel Engines, by L. E. Reed and S. C. Wallin 35

Some Factors Concerning Diesel Engine Exhaust Fumes, by J. K. Lock .. 30

Discussion 39

Session III

The Des Voeux Memorial Lecture—

Clean Air, Public Opinion and the Press, by Sir Linton Andrews 50

Progress and Research

Group 1—Research and Investigation

The Assessment of Liability to Smog in Terms of Weather, by P. J. Meade .. 58

Current Research Projects on Air Pollution by the Central Electricity Generating Board, by W. D. Jarvis and D. S. Wilson 61

Sampling for 3:4 Benzpyrene in Flue Gases from Plant Fired by Petroleum Fuels, by E. L. Howe 64

Trends in the Pollution of the Air of Great Britain by Smoke and Sulphur Dioxide, 1952–59, by J. Carroll, S. R. Craxford, H. E. Newall, and M.-L. P. M. Weatherley 71

Pollution Levels in Cities, by F. P. Williams 83

Accuracy and Reliability of Instruments in Common Use for the Measurement of Air Pollution, by S. R. Craxford, E. T. Wilkins and D. W. Slimming 89

CONTENTS—*continued*

Group 2—Domestic Heating

Report on the B.S. Coke, by J. O. Cooke and F. J. Eaton 99

Smoke Control in Action—13 Years Experience at Bradford, by D. G. Wilson 102

The Modification of Side Oven Ranges by Means of the "Cokeburn Unit," by J. Baxendale 106

Recent Developments in the Use of Gas for Domestic Heating, by G. H. Fuidge 110

Group 3—Industrial

Dust Sampling Provides Air Pollution Control, by B. Lees and M. C. Morley 117

The Prevention of Smuts from Oil-Fired Boilers at Low Loads, by F. Squirrell 121

The National Coal Board Technical Sales Service and the Clean Air Act, by A. Harrison Slade 123

Measurement of Dust Emission from Steelmaking Furnaces, by D. H. Christie, A. E. Pengelly and F. A. Gray 126

Discussion 131

Sessions IV and V—Inquiry into the Working of the Clean Air Act

Introduction 140

The Domestic and General Aspects, by W. C. Turner, M.D. 142

The Industrial Aspects, by E. M. Birtwisle 148

Tables on the Questionnaire Replies 155

Supplementary Report on Vessels 168

Discussion 171

Index to Authors and Speakers

Page
Anderson, Sir David 41
Andrews, Sir Linton 50
Archer-Burton, J. R. 39, 46
Austen, A. E. W. 47

Barnes, Councillor H. W. 46
Batey, J. W. 135
Baxendale, J... 106
Beaver, Sir Hugh 11
Birtwisle, E. M. 148
Blyth Brooke, Dr. C. O. S... .. 41
Boyd, Miss Dorothy 40, 135
Burnett, Dr. J. S. G. 171

Carey, W. F... 132
Carroll, Miss J. D. 71
Cayton, S. 171
Christie, D. H. 126
Coates, P. D... 173
Cooke, J. O. 99
Cooper, G. H. 135
Crawford, C. H. 171
Craxford, Dr. S. R. 71, 89, 137
Curtis, G. E... 173

Dawson, Councillor F. 173
Dingley, Alderman W. L. .. 46, 171
Draper, P. 45, 133
Duguid, S. N. 176

Eaton, Dr. F. J. 99, 138
Engwell, Alderman Mrs. J. H. .. 172

Feltham, Dr. P. 177
Fuidge, G. H. 110

Ginty, Councillor J. E. 134
Gray, F. A. 126
Grimmett, P. H. G... 172

Hazel, A. C. 135
Higginson, K. 177
Howe, E. L. 64, 136, 177

Jarvis, W. D... .. .. 61, 136
Joseph, Sir Keith 7

Page
Kerry, Mrs. C. M. 42

Lees, B. 117
Lister, D. 17, 48
Lock, J. K. 30

Maguire, J. 42
Meade, P. J. 58
Morley, M. C. 117

Newall, H. E. 71
Nonhebel, G. 131, 178

Parker, Dr. A. 43, 133
Pengelly, A. E. 126
Prendergast, Alderman Mrs. A. E. 171

Reed, L. E. 35

Slade, A. Harrison 123, 139, 175
Slimming, D. W. 89
Squirrell, F. 121
Sweet, Councillor I... 174

Turner, J. T... 44
Turner, Dr. W. C. 142

Vince, S. C. 44

Waller, R. E. 41, 133
Wallin, S. C... 35
Waring, G. J. 25, 49
Wattleworth, W. H... 174
Weatherley, Mrs. M.-L. P. M. .. 71
Wignall, E. W. 134
Wilford, A. T. 47
Wilkins, Dr. E. T. 89
Williams, F. P. 83, 137
Williams, R. 39
Wilson, D. G. 102, 138
Wilson, D. S. 61, 136
Winfield, E. J. 176

Yorke, P. 43

SUMMARY OF EVENTS

The Conference, held in the Royal Hall, Harrogate, on Wednesday, Thursday and Friday, October 3rd to 5th, 1960, was attended by 1,003 members and delegates. This was the largest attendance at any of the Society's annual conferences, excepting the special International Conference in London in 1959. The last time the Society had met in Harrogate was in 1949, with an attendance of 450.

With the President, Sir Hugh Beaver, in the Chair, the conference was welcomed to the town by the Mayor, Councillor Leonard Roberts, J.P. The conference and the clean air exhibition in the adjoining hall were then formally opened in the course of an address by Sir Keith Joseph, M.P., Parliamentary Secretary, Ministry of Housing and Local Government. The Presidential Address was then read by Sir Hugh, followed by a statement and appeal by the Honorary Treasurer, Mr. Stanley E. Cohen, on the Society's " Headquarters Fund " appeal. The platform party then preceded the general body of delegates on a tour of the Exhibition.

At the opening of the proceedings Sir Hugh Beaver paid a tribute to the Society's Past-President, Lord Simon of Wythenshawe, whose death had been announced that morning.

In the afternoon, Dr. J. L. Burn, a Deputy Chairman of the Council, presided over the session on " Air Pollution from Road Vehicles," at which four papers were presented and fully discussed.

On the Thursday morning the Chairman was Mr. John Innes, Chairman of the Council. The session opened with the reading, by Sir Linton Andrews, Editor-in-Chief of the *Yorkshire Post*, of the Des Voeux Memorial Lecture, on the subject of " Clean Air, Public Opinion, and the Press."

Then followed the presentation of a series of papers sent in response to an open invitation for short contributions on research and other progress reports. Fourteen papers in all were included, under the three headings of reports on Research and Investigation, Domestic Heating, and Industrial.

In the afternoon the first session on the Society's " Inquiry into the Working of the Clean Air Act " was opened with a review of the smoke control area aspects of the report, given by Dr. W. C. Turner. Mr. James Goodfellow, a Deputy Chairman, presided.

The final conference session, the Friday morning, was devoted to further discussion on the Inquiry report, the industrial aspects being reviewed by Mr. E. M. Birtwisle. Mr. John Innes was in the Chair. The conference was closed at lunch time, with an omnibus vote of thanks to all concerned with its success, and with the Exhibition, moved by Mr. G. E. Curtis of Kingswood, and carried with applause.

The Exhibition, organized by the Society in conjunction with the conference, was also most successful, thanks mainly to the excellent quality and interest of the stands of the 39 participating firms and associations.

Social events included the popular informal gathering on the eve of the conference, Tuesday evening, and a most enjoyable reception given by the Mayor and Mayoress on the Thursday evening, with dancing and a floor show. There was also a small reception by the Chairman for authors, exhibitors and the overseas delegates we were very pleased to welcome.—*A.M.*

ADDRESS

by Sir Keith Joseph, M.P.

Parliamentary Secretary, Ministry of Housing and Local Government

Mr. President, I am very honoured to have this opportunity of talking to this great conference today. I fully realize that most of the people here are experts and all are enthusiasts. During the 11 months that I have been a Parliamentary Secretary of the Ministry of Housing and Local Government I have had quite a lot of work to do connected with clean air. I started as a whole hearted believer and enthusiast for the cause. I remain an enthusiast and a believer in the cause but I am not yet, I am afraid, an expert. I know very well what a great expert your President Sir Hugh Beaver is. He can rightfully claim to have helped lay the foundation of the Clean Air Act. I know that the Society deeply regretted that owing to illness Sir Hugh was not able to attend its International Conference last year. We are all very glad to know of his recovery and that he is in the Chair this morning.

May I add a word of thanks and tribute to Sir Hugh who has, as long as I can remember, been a very kind and good friend to me personally, so that it is especially a privilege and honour to speak under his presidency this morning.

In the Clean Air Act, Parliament has provided us with the legislative tools for the job that has to be done. I am not claiming here that the Act is perfect, no Act ever is perhaps, but it does give the powers necessary to tackle the smoke menace. It is now four years since the Act was passed and the whole of it has been in operation for more than two years. It is therefore a suitable time to assess progress and consider future plans and prospects and I see with interest that you are devoting tomorrow to just this theme. It is the more relevant because during the past year there have been two important documents published. The Peech Report on Solid Smokeless Fuels and the Command Paper on Local Authorities' Smoke Control Programmes in England and Wales.

The Peech Report on Supplies of Smokeless Fuels was published in April. It presents on the whole quite an encouraging picture. The Committee found that in England and Wales the overall supply of smokeless fuels will so far as can be foreseen be adequate for the next five years after taking into account likely progress in smoke control and assuming there will have to continue to be a good deal of reliance on suitable quality open fire gas coke.

This does not mean that consumers will always be able to obtain the particular kind of fuel they prefer; in some parts of the country there may be shortages of premium fuels at times in the next three or four years, that is, unless production is expanded—a question which the producers have been asked to consider in the light of the report. But as you will all remember, the Beaver Committee always envisaged that to a large extent progress in domestic smoke control would depend on coke. The Gas Boards have done a great deal to improve the standards of gas coke produced for open fires and many are now producing it to the new British Standard Specification, the existence of which is a real step forward. Gas coke of this sort is undoubtedly an economic and efficient fuel for the domestic open fire, and I hope that any lingering prejudices against it will soon be a thing of the past.

In one part of England, the north-east, the Peech Committee Report did suggest that unless steps were taken, a shortage of open fire coke might develop and consequently the Ministry of Power are now looking into the situation there in conjunction with the Coal Board and the Area Gas Board to see what can be done.

Now I pass to the Command paper. Many of you will already have seen copies of this setting out local authority smoke control programmes. Those of you who have not can buy a copy from the department's stand at the exhibition, where you can also see some of the information from the Report shown graphically on maps in the Department's exhibit, and I won't go therefore too much into detail. But I should like to draw attention to the main points that emerge from this Report. And I apologize now for giving just a few figures.

By the end of 1958 some 120,000 premises and 17,000 acres in the black areas of England and Wales were in smokeless zones or covered by smoke control orders. The black area authorities submitted estimates indicating that they hoped to cover a further quarter of a million premises and nearly 50,000 acres by Orders made during 1959, and that progress in 1960 (nearly half a million more premises and over 100,000 more acres) would be double that in 1959. The programmes envisaged that something near the 1960 rate—that is a rate of half a million more premises and over 100,000 more acres—would be maintained in each year up to 1963, which would mean some 2¼ million premises including two million houses and nearly half a million acres in the black areas being covered by Smoke Control Orders by the end of 1963.

The actual rate of progress, Mr. President, in 1959, nearly 150,000 premises and 20,000 acres covered by Orders submitted during the year, was unfortunately considerably less than the estimates; but even so the areas covered by Smoke Control more than doubled during the year of 1959.

Orders submitted in the first eight months of this year 1960 covered nearly 160,000 premises and 30,000 acres, which suggests that 1960 may see the 1959 figures again doubled. Although this would still not catch up with the original estimates it does look as though the acceleration towards the peak rate is continuing fairly well. Once the peak is reached, and provided the momentum can then be maintained, it seems likely that, over much of the black areas, authorities will have got over the " hump " of the job by the end of the decade. If all goes well, the greater part of the County of London should be covered by Smoke Control Orders by then. This is not bad going.

On the other hand, a disappointing feature of the Report was the rather large number of authorities in areas provisionally listed as black who did not submit programmes at all. Taking a general view I think we may say that, while the programmes do not present a picture which is entirely satisfactory in all respects, they do underline the number of black area authorities who have given most serious consideration to their clean air responsibilities, and who plan to free themselves from smoke as fast as they can.

We have recently, Mr. President, asked the black area authorities to review progress made in planning and executing the programmes of domestic smoke control necessary in their areas. We hope that some authorities who have not drawn up programmes will now be encouraged to do so by the excellent example of their neighbours. We look forward to a bit of regional rivalry in this.

Perhaps also some authorities, who originally planned a slower rate of progress than those of other authorities in the area, will be encouraged to revise their programmes to bring them more into line with those of their neighbours. For our part we will do all we can to help in removing difficulties.

In particular we are anxious to avoid creating delays in the handling of smoke control orders, either in the department or at the local authority end. Recently a spate of objections, not entirely spontaneous, to a series of orders caused additional work in the department and we got a little behind, but I think we are getting over that now. Meanwhile we are seeing whether the administrative procedures we require from local authorities can be simplified. At the moment we are consulting the local authority associations about the possible abolition, in the majority of cases, of the present requirement that an authority has to submit preliminary details and obtain approval in principle before making an Order. Other possible ways of simplifying procedure are under consideration within the Department.

We recently issued to local authorities in question and answer form some material suitable for reproduction for publicity purposes, hoping that this might simplify the work of local authorities by providing them with a basis for their own publicity when they are making orders. The circular has proved quite a best seller and has gone into a second printing. We hope that suitable use of this material may decrease objections to orders and thus help to keep things moving quickly.

Before I leave the subject of local authority smoke control programmes, I should say that I have read with interest the report of the address by your Director at Aberdeen, in which he suggested an abandonment of the concept of black areas in favour of a graduated priority classification of conurbations, large towns, small towns, and rural areas.

This is a stimulating idea, but may I say that it is not so far removed from the present position as may at first sight appear? In listing local authorities whose areas appear to be black in whole or in part the Minister was merely indicating to the authorities concerned that they appeared to have a *prima facie* need for systematic smoke control.

There may well be areas outside the listed black areas where a systematic approach to more localized domestic smoke problems may be needed. The Minister will consider smoke control orders made outside the black areas on their merits. A number of smoke control areas made by authorities whose areas are not listed as black have already been confirmed.

The concept of black areas is essential in order to co-ordinate the attack on the worst areas of pollution, but it is not the intention arbitrarily to divide the country into black and white. There may be numerous " grey " areas where there is a case for smoke control.

Incidentally, as regards the smoke measurements cited in Mr. Marsh's address, I may say that there never has been a scientifically based national survey of smoke pollution in this country. Our present information is based on measurements made by local authorities and many local factors affect the siting of the gauges. One authority may only have instruments sited in what it regards as its worst polluted area or areas; another may have a more even spread of instruments so as to give a truer picture of pollution in the town as a whole. Obviously measurements from such differently sited instruments will not give comparable information for the towns concerned.

A working party representing interested local authorities and the Department of Scientific and Industrial Research has in fact been drawing up a plan for a scientifically based national survey of pollution. I very much hope that this will prove acceptable to the authorities who participate in the co-operative scheme for the measurement of air pollution, and to any other authorities whose co-operation may be asked for.

The Department of Scientific and Industrial Research distribute to local authorities who participate in the present co-operative scheme for measuring smoke a monthly annotated bibliography and other reports. This material should keep them in touch with the latest developments in air pollution research. It may be, though, that the material should reach more local authorities than it does now, and this is something which is being gone into at present.

I have spoken mainly about the responsibilities of the local authorities, and, in particular, to the attack which they are making against domestic smoke, since this seems a very suitable moment to bring under review the progress and prospects in this field.

Here, in this domestic section, we know the enemy, and we know just how to set about defeating him. What, above all, is required is zeal in carrying on the battle and effective staff work in planning and executing the campaign.

The campaign against industrial smoke presents difficulties of a different order. In some important parts of this field the most effective means of fighting the battle have still to be worked out and new weapons forged. These tasks are being tackled energetically and systematically by the Alkali Inspectorate, whose long and honourable record in combating air pollution is well known to members of this Society. I can report that there are grounds for sober optimism that the major technical problems posed by the processes which became the responsibility of the Alkali Inspectorate under the 1958 Alkali Order will eventually be solved.

The steel industry offers a good illustration of the highly technical problems which the Inspectorate are engaged in tackling. That industry is undergoing a technical revolution with the introduction of large scale use of oxygen in various processes and the resultant fume problem presents formidable difficulties. Preventive measures can be very costly—for the largest works they may go into seven figures. The Minister, however, is determined that reasonable preventive means shall be installed in this and other industries as and when they become technically effective, and it is only right that I should record the readiness of industry to accept the need for clean air and to accept the need for expenditure—often heavy expenditure—to achieve clean air.

Finally, I may say that both here and in the United States the responsible bodies are much concerned with the problem of pollution from motor vehicle exhaust gases. I see you are discussing this this afternoon. Detailed information about the steps being taken in California to deal with exhaust gases from petrol engines has been obtained and is being most carefully studied.

Some of the special measures being taken in California to deal with petrol engine exhaust gases are necessary because of the peculiar climatic and other conditions there; similar conditions are very rarely found in this country. At the moment the Americans are attempting to develop suitable devices for minimizing pollution from petrol engines, and we in this country shall be very interested to see what progress they make in this field.

Surveying the whole field of clean air, I think we can say that the achievements of the past year have not been insignificant. Moreover we have a clearer idea of the work which lies ahead, and of the time required to accomplish it. However, there are forms of air pollution about which, through no fault of our own, we still know too little to tackle effectively. One is sulphur pollution. It is unfortunately true that in spite of an active programme of scientific research in this country, supported and co-ordinated by the Government, and in spite of our keeping in touch with research in other countries, we still know all too little about the effects of sulphur pollution and how to prevent it. So far there are few indications that the scientists are near a break-through, but they will go on trying. Their efforts are by no means confined to the single problem of sulphur. They are trying to increase our knowledge of air pollution problems over a very wide field besides, ranging from medicine to industry and from shipping to agriculture. You have a session, I see, on all this research. I consider their work of the greatest importance. As our knowledge increases and our techniques improve we will be able to make further advances towards clean air.

You are, of course, all familiar with the various reasons which make the achievement of clean air such a compelling necessity. Of these, I think the health reason is the most important. Since the middle of the nineteenth century we have successfully dealt with most of the public health problems associated with the early industrial revolution. Contaminated water supplies, non-existent or inadequate sewerage, bad housing, are no longer the widespread health hazards they once were in our towns. But dirty air is one legacy of the past which is still very much with us, and is still a serious threat to health. It will surely be an outstanding improvement in environmental health if in the years ahead we succeed in cleansing the air in our cities and towns.

Hardly less important is the relief that clean air will bring to the women of the black areas. They will no longer have to spend so much of their lives washing, scrubbing and dusting the same things over and over again to keep the grime and grit at bay. Clean air is one of the biggest and cheapest labour-savers for the twentieth-century housewife and I should like to see housewives in the black areas getting together and demanding clean air, and freedom from unnecessary drudgery, as fast as possible.

This will all have to be a joint effort—local authorities, industry and the Government each have their part to play. The public too, and especially the housewife, must be convinced of the value of clean air—here some international stress is very relevant—and must be prepared to accept the changes it may involve.

The National Society for Clean Air has already done much to mobilise opinion in favour of clean air, and I hope they will long continue to do so.

Mr. President, I have the very greatest pleasure in declaring this Conference and Exhibition open.

PRESIDENTIAL ADDRESS

by

Sir Hugh Beaver, K.B.E., LL.D.

MY very first task—and I hope in this I shall have the tolerance of the Parliamentary Secretary—is to express to the members of the Society my apology and my regret that I failed so completely to attend and do my duty at last year's meeting. I should have been sorry in any case, but particularly last year because of the great occasion and because of the international nature of the gathering. Illness was my excuse but not my consolation. All that I can now say is that as one looks back over the past twelve months and as one has more time to re-read the published papers, it is seen to have been an unquestioned success—and to have contributed in many ways to the study of this long and difficult problem.

And now I turn to the much more pleasant business of thanking you, Mr. Parliamentary Secretary, for your presence and your address. If I may allow a personal note to creep in for a moment I would say that this is a particular pleasure to me because of the very happy memories I still treasure of the time in the last war when your father and I were working closely together—days so long ago that you were then not much more than an unrecognized star just above the horizon. That you have attended our Conference this year marks once again, if that were necessary, the close interest which your Ministry takes and has taken in our Society and in the work for which our Society has so long stood; and we are very grateful.

We are, too, greatly indebted to you for the admirable survey which you have made. The Committee of which I was Chairman set considerable store—as it indicated in its report—on there being established a Clean Air Council, independent of the inhibitions—as we suspected or feared—of official caution and independent of the interferences of political pressure. I well remember too how your Minister's predecessor said quite frankly that he was not going to have an irresponsible pressure group clamped on his back. It only shows that there are two points of view to everything! But I am bound to say that having now for some years seen the Clean Air Council in operation under the wise and clear chairmanship of your Minister, I do not think that there is much more that an independent council such as we envisaged would have in fact secured; and quite possibly it might have done less. We did not anticipate a vigorous and positive policy in an officially and ministerially controlled body; for that view we have I think the justification of past experience. But we were wrong. The members of my committee fully realized that the main operation would be education and persuasion; and that in our form of life and government it was not, and could not be, a matter of compulsion. Within these inevitable restrictions the Clean Air Council has unquestionably been both active and constructive.

Progress it is true has not been as rapid as we had hoped, and, as your Minister has made clear, not as rapid as he had hoped; but progress *is* being made. Some local authorities might on their own have planned to make greater speed; and some might certainly have wished to have a freer hand. But I do not know that progress has in fact been prevented by over-cautiousness or dilatoriness on the part of Government; whereas certainly in some directions there might have been even less progress if the central Government had not retained the ultimate responsibility in its own hand.

It is customary at this stage in our annual conferences for the President to deliver himself of his long cogitated views and his suggestions on various aspects of our problem; and very valuable have been many of the presidential addresses. But I am in a difficulty. I have long since, I think, said everything that I have to say, at least that I have thought worth saying. It is not possible to have been so deeply involved as I have been in these recent years, without having poured into both discussion and action everything that I could. You will therefore forgive me if I do not attempt anything of the nature of a pontifical utterance. But there are some points that I feel need to be made.

In the first place I would like to say a word on the vexed question of solid fuel. It is unfortunate—if probably largely inevitable—that we have never so far as I know had any clear direction or guidance from the Government as to the controlling principles and the desirable pattern of fuel user for the country. Almost the first thing that I asked for when I took on the chairmanship of the Air Pollution Committee was to be given some statement of the Government's policy in respect of fuel and fuel user. It was explained to my committee that it was in fact impossible to lay down a long term policy as between coal and gas and electricity and oil and atomic power; and certainly if one considers the extraordinary changes and wide variations which we have experienced in these post-war years, one would, to be fair, have to sympathize with anyone charged with the production of a national fuel policy. I do question whether there might not have been more guidance. Just think of those years; the coal famine of the years immediately after the war; the poor qualities of coal so often then supplied—nutty slack for instance; the endless electricity cuts; the inability to export any of our coal—to Ernest Bevin's continual lamentations;—the vastly increasing demands for petrol and diesel oil; the growth of supplementary chemical industries entirely dependent on the working of imported oil; the challenge and rosy promises of atomic power, now no longer so promising—at any rate in the nearer future; finally the shattering near collapse of the coal trade. Much of this was inescapable, but was it all necessary? One must indeed sympathize with the coal merchants who in this single decade have seen such a complete reversal of conditions from an out-and-out sellers' market to their present most difficult and in some ways almost precarious position in an uncertain consumers' market.

But in spite of all these uncertainties, there has in fact been no change in the basic problem as to the means of securing clean air so far as the main fuel is concerned. The problem that faced the Government in regard to any national fuel policy, also faced my committee in its search for a clear and workable formula for clean air. My committee for itself concluded that the great bulk of the fuel to be used in a clean Britain would still be solid fuel in solid fuel-using appliances. That I believe to be absolutely the position still. In the present state of knowledge and development, that must mean for the vast majority of individual users one or other of the types of smokeless fuel including of course low volatile coal; but coke—the right type of coke—is still and must be the major weapon. I would like here to pay tribute to the work of the British Standards Institution on the Standard published last year for Coke for Domestic *Open* Fires. This carries us a considerable step forward in the solution of the most difficult part of the problem of providing a perfect coke. There have too been great advances in the proved practicability of the production of good reactive coke from coals hitherto considered to be non-coking; and there have been most encouraging results from the N.C.B.s, and other, experiments in the production of various forms of smokeless fuel; as well as of clean coal, where my predecessor Dr. Lessing blazed the trail 40 years ago. All this is excellent, though it is taking rather a long time.

There may well in due course be

developed domestic heating appliances which can safely use many of our raw coals without nuisance and without skilled, or at least without skilful, and continuous attention. But these have not yet been developed. So if we believe in clean air, if we believe that too long have we subjected ourselves and our children and our aged to the unquestioned and lethal dangers of foul air, we must accept that there must in due course be some control over all domestic firing appliances wherever people are thickly congregated; or over the fuel used—or both. In industry it is as we know perfectly possible to use in nearly all boilers and furnaces the poorest of coals so as reasonably to fall within the Act. This is not so and probably never can be the case with the domestic hearth. I would not like to leave this here without paying tribute to the work of many people in helping to solve the domestic problems —the Director and Staff of B.C.U.R.A. and Sir John Charrington among them; and perhaps above all the several women's organizations, which play such a vital part and have done such valuable and public-spirited work. The results can only be achieved by the united efforts of all concerned. In this connection it is of interest I think to note that in the U.S.A. the bituminous coal industry has established a full time staff of experts headed by Harry C. Dollman, well known in the air pollution world in the States, as its director. " Industry," he has said, " is aggressively moving forward to solve air pollution control problems and the Air Pollution Department of the National Coal Association has been created to aid this movement."

This naturally leads one to a word on what has already been achieved in industry here generally. It is pretty remarkable. There are many processes which have yet eluded cure—largely because of the cost. In a country so small and so heavily populated as ours, which has to maintain itself against overseas competition that is increasing yearly with terrifying speed —with the new vast industrial developments in so many other countries, with new competitors joining our old competitors—it would be completely unrealistic to place such a burden on our own industry as would be involved in the immediate compulsory modernization of all plant and equipment that uses fuel. But no one can go through the country without seeing for himself what an immense improvement has been achieved in regard to large furnaces and steam-raising plant. Where they are available the results of systematic air sampling in many places bear this out to a marked extent.

It would be impossible here to attempt to give even a summary of all the work that has already been done in the industrial sector. I would commend to you the Chief Alkali Inspector's Report which does, too, underline the immense difficulties, technical and financial, that are involved in many of the long-standing processes of our country. But there are a few points I would like to make—a few salient points.

The heavy chemical industry has expanded about threefold since the last war. New industries, *e.g.* man-made fibres, bromine from seawater, carbon-black petrochemicals, have developed; and all these plants have been fitted with fume, dust, etc., treatment plant to the satisfaction of the Alkali Inspectorate.

Oil refining has in this same period increased from 2·5 to 40 million tons per annum; and the comparative freedom from major complaint shows the efficacy of the means taken. The whole of the expansion has been by plant to the satisfaction of the Alkali Inspectorate.

Cement production has doubled. All new production and much of the old has been fitted with dust arrestment plant. The dust problem on Thames-side remains a serious problem; the only cure, precipitators and high chimneys, has to be measured, in cost, in terms of millions of pounds.

All the new power stations are virtually smokeless, with very high performance grit arrestment plant and the latest with high chimneys (up to over 500 ft.). Older units with their low chimneys and sub-standard grit arrestment plants are still the cause of trouble and complaint, but they are steadily on the way out. No grit arrestment and no sulphur treatment plant has yet been proved to be hundred per cent successful. An efficiency of grit and dust arrestment of 97 per cent+ still leaves a serious if much localized problem; but the advance has been immense.

The iron and steel industry is embarked on a very costly campaign to deal with emissions from ore driers, sinter plants, blast furnaces and the new techniques of steel production. At the new steel works at Newport the capital cost of gas and fine dust prevention in all directions will run into millions. The gas industry is steadily getting rid of horizontal retorts.

The coking industry has a working party with the Alkali Inspectorate to investigate the whole matter of " green gas " from the charging of ovens. The latest ovens completing or planned (S. Durham Steel at Greatham and Richard Thomas & Baldwins at Newport) are fitted with double collecting mains. The ceramic industry is now seriously concerned. Mechanical stokers are steadily replacing hand firing. The bottle oven of the Potteries is rapidly giving way to smokeless techniques such as tunnel kilns. There are working parties with the Alkali Inspectorate to examine the specially difficult problems of salt glazed ware and blue engineering bricks.

Each industry brought under the Alkali Act by the Order of 1958 has its organization to discuss its problems with the Chief Alkali Inspector so as to arrive at a national policy; and all new plants erected must be fitted with " best practicable means " to deal with their emissions. But there are still problems where as yet we can see no answer. To these last Mr. Nonhebel's paper has been a real contribution. Where no solutions appear likely in the near future, tall chimneys have been required to aid dispersal and reduce ground level concentrations; that is the best that can be done with present knowledge.

As can easily be seen from this brief summary, during the past few years industry has done much and has already spent or allocated millions of pounds to clean air measures.

Many industrial processes did in fact from the outset come under the control of the Act; but I know that some local authorities feel that too few have come under their control. The Minister's recent decisions in regard to Manchester, Sheffield, and Liverpool show how the wind is blowing, and that where the answers are really known and where a local authority really has adequate technical and experienced staff, the long-term policy of Government is to bring industrial processes increasingly within the direct control of the Act.

I would like to turn for a few minutes to the question of research, and with that and in that I include every stage of research not only the fundamental work, the establishment of the basic facts and truths, but also all the means of their application, as well as the dissemination of the information in appropriate terms to all the people who are or ought to be concerned, the design of the best equipment whether for using fuel or measuring air effluent; and I would add the education of all and sundry as to the facts, the dangers, the methods, the benefits. Anyone who attended the Society's Jubilee Conference last year must have been struck by the almost world-wide interest that was shown; the Society has every justification for including now in its quarterly publication, *Smokeless Air*, an International Section with Honorary Correspondents already acting for South Africa, Norway, West Germany, Italy, the U.S.A., Ireland, France, Belgium, the Netherlands and Poland. That there should be this widespread and growing interest is excellent; but it does mean that there must also be means of pooling—as far as that is practicable—the knowledge that is being so busily collected all over the world. It is unfortunately almost impossible to find any sure means of completely securing this pooling of knowledge; and so inevitably there is a great deal of duplication of effort. If this problem has proved intractable even within one single country, how much more difficult now that so large a part of the world is actively interesting itself. That there is immense effort being put into this whole question is undoubted. The Clean Air Council had a little while ago a quite imposing statement laid before it, of the research work at present being officially carried out or sponsored in this country; and recently I was looking at a statement of the official work being done in the U.S.A. which had been published by the U.S. Public Health Services, covering the year 1959. There were something between 80 and 90 major research projects being carried out by Federal bodies and over 70 other research projects in non-Federal institutions covered by Federal grants. I was, also, favoured with the syllabus for the Third Air Pollution Research Seminar which was held at New Orleans in March of this year—in which papers were presented for discussion from nearly half the States in the Union as well as from Canada, U.S.S.R., Mexico and Great Britain. I mention these points to give you some idea of the immense interest in, and the immense expenditure on, research all over the world but particularly in the U.S.A. This too is borne out by the bulky Digest of State Air Pollution Laws that has been recently produced by the U.S. Department of Health Education and Welfare. When you remember that every one of the 50 States has its own laws on this subject, and that every municipality is largely its own master in this problem of clean air, then we may indeed be thankful that here in this country we are in this respect so much better off—even if we do not yet feel that everything is as it should be.

All this shows you too what an amount of knowledge and experience, of trial and error, of half-truths, and likely and unlikely causes and cures, there are, through which those responsible have to thread their difficult path. I do not think that there is anything more that the N.S.C.A. with its slender resources can do, to filter as it were and digest all this material for the better guidance and assistance of those concerned; but it does seem that the Ministry or perhaps the D.S.I.R. at Warren Springs might consider this matter further. It is a real problem.

Before leaving the activities in other countries I too must refer to what I think is one of the most exciting pieces of news from the air pollution front, namely the passing by the California State Legislative of the first act directed at motor exhausts. I do not mean smoke or visible exhaust. A Motor Vehicle Pollution Control Board has been established to administer the new powers, and in particular " to determine and publish the criteria for approval of motor vehicle pollution control devices " and to approve and issue certificates of approval for such devices. As soon as there are *two* approved devices, then from one year after that date no new motor vehicle will be registered in the State of California unless it has an approved device; and this rule will apply within the following two years thereafter to every motor, private or commercial, that changes hands. That this should happen first in Los Angeles is not surprising, because as Smith Griswold, its very effective Air Pollution Control Officer, states in his latest review of his department's activities, it is now completely established that the operation of gasoline-powered vehicles accounts for the lion's share of the notorious Los Angeles smog. There is no other part of the world I believe where quite the same compelling causes operate, but there is no doubt that every populous country must give increasing and urgent thought to the problem of automobile exhausts—as well as to the general question of gases in the air; and it is well that publicity should be given here in this country to such developments and actions elsewhere, because we also will have to face this sort of action—remembering too that our fuels, liquid and solid, have a far higher sulphur content, and to that extent are probably more dangerous, generally, than most of the fuels of the U.S.A.

I quote this as just one example of the many developments and wide ranging activities that have been occurring since my committee reported. The future will see many more, and it is essential that we keep abreast with all this information so that the latest improvements and inventions should at least be incorporated into any new designing or planning. That is why I have stressed this question of publicity; and that I feel must always be the keynote and a main objective of each annual conference of the National Society for Clean Air.

THE ADMINISTRATIVE CONTROL OF SMOKE FROM ROAD VEHICLES

By

*Douglas Lister, F.R.S.H., F.A.P.H.I.**

Summary

The problem of air pollution from road vehicles is causing increasing public concern. It may be divided under the two heads of visible smoke and invisible gases. As is the case with pollutants under the Clean Air Act, the visible smoke can be dealt with and is taken notice of by the law, while the invisible cannot yet be dealt with technically and therefore does not come under the law. The number of vehicles is continually increasing. Heavy black smoke appears to come from comparatively few offenders, more actual pollution coming from those vehicles emitting a moderately heavy smoke. Legal power is needed if a really effective clean up is to be secured.

The present law is difficult to enforce, because of the need to prove damage or danger, but the police are increasing the number of cases they are taking to court. There is a need for a standard similar to the Ringelmann chart. The Ringelmann chart is used by the State of California. Air Pollution Control Officers are used in California to enforce law. They are also used in Durban, operating via police. The use of the Ringelmann chart presents difficulties with moving vehicles, and the use of either the Hartridge smoke meter or the Bosch instrument using filter paper is discussed. In Durban the law is enforced by removing the clearance certificate of a vehicle until the smoke causing fault is remedied. A great deal of pollution from petrol vehicles will be cured when traffic congestion is eased.

THE problem of air pollution by road vehicles is one which has engaged the attention of this Society in increasing measure in recent years, and many interesting contributions on the subject can be found in past Conference Proceedings and in the Society's journal. From press correspondence and other public references made to the annoyance from motor vehicle exhausts one may sense a growing impatience on the part of the public, and although no well-informed person would claim that the actual pollution from this source is as serious as that from domestic fires and industrial furnaces, nevertheless it does represent that part of the total aerial nuisance which occurs literally under our very noses, and for that reason alone it cannot be ignored for long.

Pollution from internal combustion engines may be divided under two heads: (*a*) visible smoke, and (*b*) invisible gaseous constituents. In the present state of our knowledge, the first is preventable, but practical means for dealing with the second are less apparent; therefore the existing law (such as it is, as will be examined later) rightly takes account only of visible emissions, and there are no legal sanctions which may be invoked against the other half of the problem—the carbon monoxide, hydrocarbons, aldehydes and nitrogen oxides which in combination produce the characteristic " exhaust " smell in our congested urban streets.

One is immediately struck by the fact that there is here a parallel with industrial and domestic pollution as recognized by the Clean Air Act, where there is smoke which is preventable by enforcement of the Act, and there is the invisible problem of sulphur as yet unsolved and therefore incapable of being dealt with by law. From time to time one reads ill-informed criticism that the Clean Air Act does nothing about sulphur pollution, but no one in

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* County Health Inspector, Northumberland.

TABLE 1

	Exhaust Condition				*Total*
	Clean	*Visible*	*Moderately Heavy*	*Heavy*	
Public Service Vehicles	11	27	21	—	59
Goods Vehicles ..	162	96	74	5	337
Total	173	123	95	5	396

his senses would suggest that the drive against smoke should have been delayed on the grounds that it only dealt with the easy half of the problem. Research is (we hope) continuing on sulphur, but in the meantime we are deriving great benefit from the reduction of smoke. It is suggested that the time is now ripe for similar vigorous action against unnecessary smoke from vehicles, while the possibility of dealing with gaseous pollution is being further investigated. The aim of this paper will be to consider what methods might be adopted to that end.

Before doing so it might be worthwhile to look at the extent of the problem. The traffic in Great Britain has the highest density in the whole world, and is increasing at an alarming rate. The total number of vehicles in use in this country is now approximately nine million, of which three-quarters are private cars and motorcycles. There are about 1½ million commercial vehicles, passenger and goods, of which some three hundred thousand are diesel-engined. All of these vehicles emit polluting gases, but for our present purpose it is necessary to form an estimate of the proportion of them which are generating unreasonable and avoidable smoke, and here the complaint is principally, and justifiably, against the diesel-engined group. There appears to be no published information upon which to rely, so during the preparation of this paper some observations were carried out on diesel-engined traffic on a hill situated on a main trunk road in the North of England, with the results shown in Table 1.

Some explanation is necessary of the classifications used for smoke density, and attention is now directed to Figure 1, which is reproduced by kind permission of the British Petroleum Co. Ltd., and which shows photographs of diesel exhaust smoke taken against a white background and giving the percentage light absorption in each case as checked against a smoke meter. In the observations, which were taken over five half-hour periods, "visible" smoke means 30-50 per cent. light absorption, and up to the density shown in the second picture; "moderately heavy," up to 70 per cent. as in the third picture; while "heavy" smoke was taken as anything over 70 per cent. These classifications must be considered

Light absorbed, per cent.

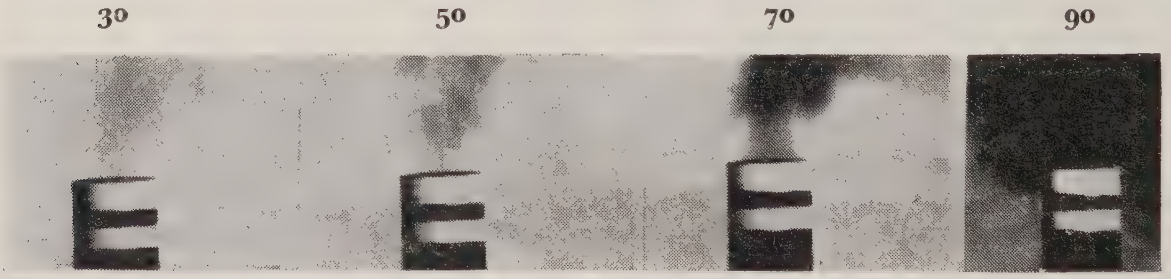

Fig. 1. Automotive exhaust smoke viewed against a white background

as being very approximate, and indeed the figures in the table must be taken with a certain amount of reserve: assessment of smoke density against a moving background and having regard to the wide variety of outlet pipe positions found on goods vehicles is anything but precise. (Passenger vehicles are required by law to have their exhaust outlet clear of the vehicle and to the offside, which renders them somewhat easier to observe; only one heavy goods vehicle having a vertical exhaust pipe was encountered amongst all these, and here assessment was of course no problem at all).

The following comments may be made, arising from these observations. First, although the public outcry is chiefly against the vehicles which are laying a smokescreen across the road, and which are thereby open to prosecution, these appear to represent little more than 1 per cent. of the total, and there must be far more actual pollution caused by the greater number emitting a moderately heavy smoke. Secondly, the public service vehicles have come out better than the worst lorries, but not as good as the best, although it should be noted that the numbers observed were perhaps insufficient for a firm conclusion to be drawn, and moreover, about 80 per cent. of the buses were from the same transport undertaking. Finally, although many of the lorries climbing the hill with a clean exhaust were, as might be expected, travelling light or with small loads, a considerable proportion succeeded in doing so with what appeared to be a full payload; conversely, by no means all of the vehicles emitting unreasonable amounts of smoke were fully laden.

The factors causing emission of smoke from diesel engines have been enumerated many times by contributors to the Society's proceedings, and other technical papers are to follow at this session, so that no more time need be taken up over this except to say that in almost all serious cases there is involved some act, default or neglect on the part of the vehicle operator. It has to be accepted that by the nature of things there must be more particulate matter even in a good diesel exhaust than in that from a petrol engine. The possibilities of further improvement in this direction will no doubt be discussed by the experts later. In the meantime, if we content ourselves with the immediate objective of tackling what may be considered reasonably practicable, dealing only with those cases where anything denser than merely " visible " smoke (as defined above) is being emitted, then on the figures obtained in the observations some 25 per cent. of the diesel-engined vehicles on the road are going to be involved. How then may we set about this?

Reading the many opinions expressed on the subject, both in technical papers and in the public press, one finds two schools of thought: first, that " the police ought to be doing more "; and second, that the proper method should be education and propaganda amongst vehicle operators and their employees.

To dispose first of the latter alternative, this has a familiar ring to those of us who are engaged in public health work. For many years now, a stream of health education has been directed at persons engaged in the food trades, with a view to promoting clean handling of foodstuffs, but until the advent of the Food Hygiene Regulations in 1955 (defective though they may be), too often one found oneself making little impression and merely preaching to the converted. The existence of adequate legal power is unfortunately essential before certain persons will become amenable to advice or exhortation. The necessity is not for an orgy of prosecutions, but for a law which will command the respect of those who are to obey it. How far in road traffic legislation are we short of having such a law, and this then brings us back to the first point: what more, if anything, can the police be expected to do?

The present law regarding the emission of smoke is contained in Regulation 79 of the Motor Vehicles (Construction and Use) Regulations, as amended in 1957, when an important change was made in the wording. It will be remembered that for a prosecution to succeed before 1957, one of two things had to be proved: either that the smoke was preventable or that it was harmful. The second alternative was never very useful for smoke cases: however strongly one may feel about exhaust smoke, the blunt fact is that there is even today no information which would be accepted in a court of law as proving that any person might be suffering direct actual harm therefrom. (Contrast, for instance, a person burnt by cinders from a steam traction engine). To succeed on the other count, it was necessary to prove that the smoke was preventable " by the taking of any reasonable steps," and the defence could take refuge in asking what steps should have been taken. The answer to that question could in certain circumstances involve a partial dismantling of the vehicle engine, and even then, if the remedy were found to be not a simple re-adjustment but a complete overhaul requiring a week in the workshop, could this be held to be a " reasonable step " in the middle of a firm's busy period?

Following representations that this law was difficult of enforcement, the 1957 amendment resulted, which immediately made no longer relevant the question as to whether the smoke could have been prevented or not. The emission of smoke became an absolute offence, *provided only* that it was likely to cause (*a*) damage to property or injury to person, or (*b*) danger to person. What has been the effect of this change? Again, the first alternative of " damage " or " injury " is of little use against internal combustion engine smoke, which leaves only those cases where the amount of smoke is such as to impair visibility to the prejudice of road safety. Fears were expressed at the time that there might be even fewer prosecutions as a result of this amendment, but reference to Table 2, showing the number of offences proceeded against by the Metropolitan Police (the only readily available statistics on the subject), shows that this has not been so, that there has been an increase, though not a large one, in the cases taken to court.

TABLE 2

Year	*Total Offences*	*Cautions*	*Summons*
1954	19	18	1
1955	158	146	12
1956	164	120	44
1957	121	78	43
1958	174	106	68
1959	173	101	72

What appears to be happening is that the police, finding a vehicle laying a smokescreen across the road, are now able to proceed confidently without having to worry about a possible defence involving " reasonable steps " or preventability; but it is no longer possible to deal with a less dense emission by alleging it could have been avoided (which in very nearly all cases it most certainly could).

Referring again to Table 1, this means that under the present law, just over 1 per cent. of the diesel-engined lorries observed might possibly have been the subject of police action, but the 25 per cent. unnecessarily emitting moderately dense smoke (and causing in the aggregate more nuisance) would do so with impunity. It is hardly surprising therefore that before the amended law has had three years' experience behind it, there have been further representations to the Minister of Transport, and several questions in Parliament on the subject. There is now some agitation for the scope of the Regulation to be widened to include, as well as " injury " and " danger," such terms as " annoyance," " inconvenience," or " discomfort." This does not have the wholesale support of the police, upon whom would fall the burden of proof of such vague allegations. It must be borne in mind that such cases as are at present taken are so flagrant that little defence can be offered, and they frequently are in fact undefended; if the law is to be strengthened for an all-out attack to be made on smoke on the roads, it is quite likely that there will be some organized opposition on the part of vehicle operators.

Let us look for a moment at the history of smoke abatement law generally. Under the old 1875 Public Health Act, an industrial chimney could only be dealt with if " sending out black smoke in such a quantity as to be a nuisance." How many prosecutions were possible using such vague terms, until the power to make byelaws laying down permitted periods for black smoke did away with the need to prove nuisance? There was, however, still the difficulty of defining " black smoke " until the 1956 Clean Air Act finally took advantage of the scientific method of smoke estimation available in the Ringelmann Chart. The conclusion is inescapable that for road vehicle smoke a similar course is going to be necessary. Such a trend is in fact to be seen in recent legislation in certain other countries.

In the State of California, U.S.A., the relevant road traffic law, administered by the State Highway Patrol, states that " no motor vehicle shall be operated in a manner resulting in the escape of excessive smoke, flame, gas, oil, or fuel residue," and in 1949 an order was made to the effect that " a motor vehicle shall be considered to be emitting ' excessive ' smoke if on visual comparison for a reasonable period the exhaust products have a density equal to or greater than No. 2 on the Ringelmann Chart." In addition to this law, in that part of the State covered by the Air Pollution Control District organization of Los Angeles, the Health and Safety Code containing their general smoke abatement law does not, as in this country, exclude such things as motor vehicles—the operative words are " shall not discharge from any single source of emission whatsoever . . ." and the air pollution control officers have specific power to " stop, detain and inspect any vehicle designed for and used on a public highway." Penalties are provided for a discharge of more than three minutes in any hour of smoke equal to or greater than Ringelmann 2, *or* smoke not being black but having a similar degree of opacity, and there is an additional clause forbidding emissions which " cause injury, detriment, nuisance or annoyance to any considerable number of persons or to the public, or which endanger the comfort, repose, health or safety of any such persons or the public, or which cause or which have a natural tendency to cause injury or damage to business or property." Finally, in 1957 the air pollution control officers were given the power to enforce the road traffic regulation on smoke on the same footing as the highway police, the view being expressed that such activity " should be the common law responsibility of all local law enforcement agencies."

Two interesting points for discussion emerge here. First, the use of officers other than the police to administer a road traffic law. This suggestion has already been made in this country, by some local authority organizations, and in other places. The original Beaver Report referred to it: although the view was there expressed that the existing law was " explicit and adequate "—a view which as we have seen was perhaps a little over-optimistic—the Committee in acknowledging that the police " had much else to do," went on to say that " It is a matter in which the local authorities should be able to assist." Is there, then, a case for following the Californian example by extending our Clean Air Act to include vehicles, and/or by giving local authority officers power to enforce Regulation 79 (or some improved version of it)? Whilst leaving this question unanswered for the moment, it must be admitted that there are some arguments against, particularly that the power to stop a motor vehicle and question the driver is in this country a police prerogative, and any departure from that principle would require very serious consideration.

The other matter of interest is the

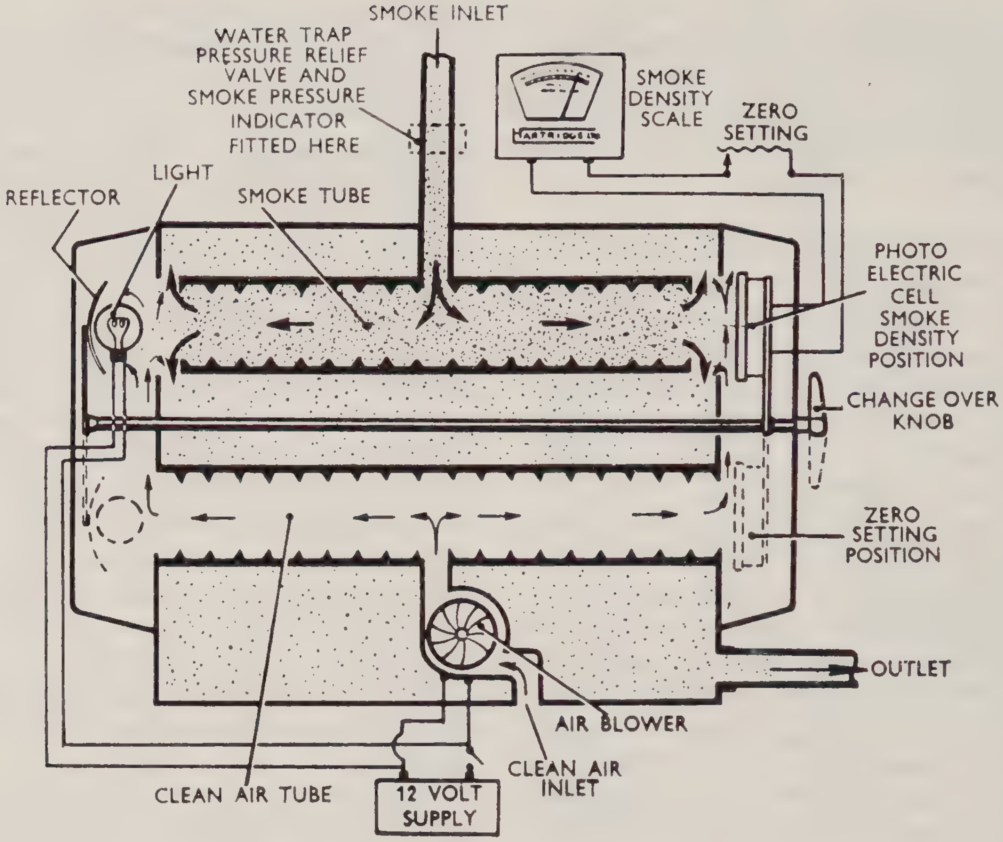

Fig. 2. Diagram illustrating the working principle of the Hartridge–B.P. Smokemeter

use of Ringelmann shades for vehicle smoke. Micro-Ringelmann charts are issued to the Californian patrolmen, but do not appear to be used in practice. All officers receive a course of instruction in recognition of smoke density, and local courts have upheld this technique. Nevertheless, assessment of smoke from moving vehicles must present the same difficulty as was experienced by the writer in carrying out the observations referred to earlier, except that in America vertical exhaust stacks are more often fitted to heavy commercial vehicles. It does, however, seem safe to say that if visual observation using Ringelmann or other standards is to be relied upon, the permissible level of smoke must always be a fairly high one, and it has been the opinion of the writer for some time that some more objective method of smoke measurement will have to be employed before any real progress can be expected.

Such objective measuring devices do in fact exist, and examples of two types will now be described. The first, the Hartridge-BP Smokemeter, works on the principle of the comparison of the density of a column of smoke with a column of clean air, in tubes which are optically and dimensionally identical. (See Figure 2). At one end of the tubes there is a light source, and at the other a photo-electric cell, mounted on swinging arms so that they can be together moved from one tube to the other. The photo-cell is connected to a micro-ammeter having a smoke density scale reading 0-100, representing percentage light absorbed. A constant flow of clean air is arranged to avoid soot building up on the light source and the cell and so interfering with the instrument's accuracy. The device can be connected to an exhaust pipe in a matter of seconds and, allowing for a short warming-up period, the whole of the checking may be carried out within a few minutes. This meter has been approved by the Air Pollution Panel of the British Motor Industry Research Association for research work, and the road authorities in Belgium are known to be experimenting with a view to its official adoption in that country.

The other type of instrument such as developed by the Robert Bosch Company in Germany uses a filter-paper disc through which a measured quantity of gas (330 c.c.) is drawn by a pneumatic pump clamped to the exhaust pipe (Figure 3) and capable if desired of being operated by remote control from the driving cab for tests on the road. To avoid errors in visual comparison of the darkened discs, these are evaluated in a separate photo-electric unit giving a direct reading on a micro-ammeter, in this case on a scale reading 0-10. The advantages claimed for this meter are that the delicate photo-electric part of the equipment does not require to be carried on the vehicle during testing, and that the filter-paper discs form a permanent record available for later use. Against this, the criticism can be made that only a relatively small sample of the gas is taken for measurement at any one time, and such a meter cannot show the constantly changing density of exhaust gas.

An approved smoke-meter in the hands of the police, the official vehicle-testing stations, or the traffic examiners of the Ministry of Transport, could be made an effective weapon in the drive against diesel smoke. To test at regular intervals three hundred thousand road vehicles, or even the worst 25 per cent. of them would be a formidable undertaking, but this would not really be necessary. All that would be required would be the power for the police (or any other enforcement authority) to refer for testing under controlled conditions any vehicle seen to be smoking excessively; if the test confirmed their opinion, the vehicle (and its owner) could then be dealt with as appropriate. The improvement in exhaust condition would not be confined to those vehicles actually tested: obviously all operators would endeavour to keep themselves out of the hands of the testing stations, if only because of the loss of time involved. (Another advantage would be that the acceptable standard could be altered at any time as might be found expedient, simply by the official substitution of a new permitted number on the scale).

Such a scheme is perhaps not as revolutionary as at first appears, because a variant on it is being successfully worked in the City of Durban, South Africa, and those who attended last year's International Conference of this Society may remember a reference to it by that city's Air Pollution Control Engineer, Mr. K. R. Johnson, to whom acknowledgment is made for these further details in amplification of the paper he then presented. In addition to a road traffic law similar to our own prohibit-

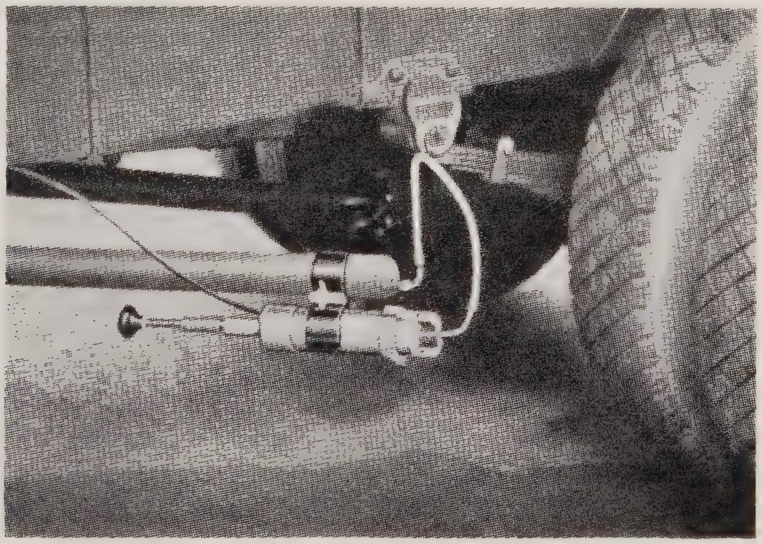

Fig. 3. Bosch sampling pump installed on vehicle

ing smoke which is a nuisance or interfering with visibility, there is a provincial ordinance regarding unroadworthy vehicles, providing for their removal from the road, again much as in this country, but with this addition, that " where it appears to a police officer . . that the emission of smoke or fumes from a vehicle is due to a defect therein," it can be dealt with as unroadworthy. Quoting from Mr. Johnson: " In practice the Air Pollution Inspectors report all vehicles seen emitting excessive smoke and the eight worst vehicles are referred to the Police the following morning. The Police are then responsible for directing the vehicle to the Municipal Testing Ground where tests are made simulating road loaded conditions. If the examination, in which a smoke meter may be employed, confirms excessive smoke emission, the examining officer removes the clearance certificate so that the vehicle cannot be used until the defect has been remedied. Prosecutions are therefore avoided, and in the 700 cases where vehicles have had their clearance certificates suspended, the Legislation has not been challenged." (It will not escape notice that here again we find the local authority air pollution staff working in association with the police).

So far, no mention has been made of smoke from petrol engines, but this, being generally a more transient phenomenon, is harder to deal with legally. However, except for the small " petroil "-lubricated two-strokes, mainly motor-cycles and scooters, which are a special problem for which it is difficult to see a simple remedy, no petrol engine should ever emit more than a minimal quantity of visible smoke, and an engine with a heavy consumption of lubricating oil and generating a continuous blue fog is due for an overhaul in any case. There seems to be no reason why a similar procedure to the foregoing could not be evolved to deal with such cases. There is this important difference: a diesel smokes when it is being worked hard; a petrol engine is at its worst from the point of view of both visible and invisible pollution under conditions of intermittent operation, as in congested town traffic. In fact, one of the most practical ways of alleviating the nuisance from petrol engine fumes in this country, where there are no special circumstances such as obtain in the Los Angeles basin, would be by road planning to keep urban traffic on the move, and when possible away from shopping and business precincts, so reducing the amount of polluting matter generated, and at one and the same time aiding its more rapid dispersal. Fortunately, if only for economic reasons, this policy is likely to be forced upon us in increasing measure in the future.

PREVENTION OF AIR POLLUTION BY DIESEL-ENGINED ROAD VEHICLES

By

*G. J. Waring, A.M.I.M.E.**

Summary

It is necessary for the diesel designer to design his engine so as to reduce smoke emission, for both economic and amenity reasons. There is need for a means of measuring smoke emission and for a standard of smoke acceptibility. The Hartridge smoke meter fulfills the need for an instrument which gives an instantaneous reading, is portable and does not rely on special services for operation. It operates by measuring the obscuration of a beam of light falling on a photocell, and showing this as a direct reading in percentage smoke. Other forms of smoke-meter working on the filtration principle are not so convenient, particularly for roadside use, although they do have the advantage of making a permanent record. Diesel engines have limiting points of clean running which can be reached by reducing the engine speed or fuel quantity; if these are well up in the speed range then the engine is a good one. It is suggested that a new engine should have an exhaust of under 25 per cent. obscuration as measured by the Hartridge meter, that the allowance for engine wear should be up to 45 per cent., and that 60 per cent. should be the " condemnation " limit.

The poor combustion which gives rise to smoke can be the result of a number of factors such as faulty injection equipment, lack of cylinder compressions and interference with the air breathing of the engine. The paper describes these faults in some detail.

TO the diesel engine specialist exhaust smoke means engine inefficiency. Smoke is the telltale that the engine is unable to digest its fuel completely and this becomes a double burden to the user in the forms of loss of engine performance and fuel wastage; both cost money. To the man in the street, vehicle exhaust smoke is a nuisance. It is something he can see, smell and noticeably feel its effect on breathing and sight. He dislikes any of these feelings immensely. Thus, the diesel engine manufacturer is morally compelled to do his utmost by way of design and workmanship to produce engines which are to all intents and purposes smoke free. Additionally this objective must be sustained over extended running periods. There is, therefore, a high premium on engine durability and stamina as well as performance.

These qualities are not just designed so simply into the engine. It could be said that 85 per cent. of the desirable qualities of a diesel engine covered by general overall performance can be guaranteed straight from the drawing board. The remaining 15 per cent. has to be obtained by experimental and development know-how. As every single per cent. of performance is gained it becomes progressively more difficult to claim the remainder. As this important phase of development proceeds, there is one outstanding factor which dictates the progress on the scoreboard; that is exhaust smoke emission.

Smoke to the Development Engineer limits engine performance; in one direction the limit is on B.M.E.P.† or the torque output, and in the other it is on the speed range or maximum B.H.P.† The manufacturer wants both high B.M.E.P. and B.H.P. coupled with a good specific fuel consumption in order to sell his engine. None of these vital necessities can be achieved with a dirty exhaust.

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* Development and Proving Engineer, Leyland Motors Limited.

† Brake Mean Effective Pressure and Brake Horse Power.

Means have to be devised for measuring exhaust smoke emission and some standard has to be set up for smoke acceptability from both a density and volume aspect. The experimental engineer can use well-trained eyes for visual observation to a degree but it takes a correctly designed instrument to register any minor changes in exhaust due, for instance, to some experimental feature being tried out on the engine. It is believed that the ideal smoke measuring meter would be one that gives an instantaneous reading and would therefore follow any change in exhaust discolourization immediately, would have portability and not rely on special services for operation. The Hartridge-BP meter fulfills these requirements very well. With this instrument the engineer can assess his engine performance against a smoke scale very quickly and set the engine output within a specified smoke range; that is, the meter becomes a " Go " or " Not Go " gauge. It works on the light absorption principle.

The meter consists of a photo-cell and light which may be placed at will at opposite ends of either of two tubes, by means of a hand lever. One tube is supplied with clean air by means of a small blower, to provide a zero reference, while the other has a central tapping which can be connected to a sampling pipe in the exhaust line. The air flow restricts the exhaust gas to the exhaust tube and also flows around the lamp and photo-cell, helping to keep them clean. The exhaust gas flows outwards in its tube, through radial holes at the ends, into the casing and thence out via pipes connected at either end of the casing.

The exhaust gas obscures the light falling on the photo-cell, thus causing a reduction in the current measured by the micro-ammeter which has a reversed scale and therefore gives a direct reading of per cent. smoke. The only services required to operate this instrument is a D.C. supply from a good healthy 12-volt battery.

Other forms of Smokemeter are not so convenient to use as this. They usually work on the filtration principle. A known quantity of smoke is made to pass through the special disc or strip as the case may be of filter paper which is inserted in the sampling probe. This is connected to a vacuum pump which is controlled by a time switch in the case of disc filters or continuously moved at a pre-determined speed in the case of strip-type filter paper. In either case the exhaust gas is drawn through the filter paper for a definite period of time. The duration of this time is obviously very important as the discolourization of the filter paper by the exhaust smoke is dictated by the time exposure. After the test, the filter paper is removed and the amount of smoke is determined by comparing the degree of blackening with a scale provided with the instrument or compared visually by means of a photometer. It can be quite a lengthy process using this type of instrument to record exhaust smoke density and it is doubtful whether it could be used with accuracy and the speed required for snap checks, for instance at the road side, but it has one redeeming feature if used in a laboratory that the records of smoke are permanent and can be filed with other engine data.

These meters measure the density of the exhaust, and not the volume. There are no ready means of measuring the volume of gas emitted from an exhaust pipe. It is, however, most important that volume be considered as it stands to reason that a tiny exhaust pipe from a small engine, even though discharging a " dense " exhaust is a far less atmospheric pollutant than a less dense discharge from a big engine's big exhaust pipe.

In co-relating density and volume to an acceptable limit, the engineer's eye is usually the judge of the exhaust of the engine he is working upon.

As mentioned earlier, the smoke limits of any engine are reached by either pushing the speed range too far or by admitting too much fuel in order to lift the torque output. If you went the other way, i.e. reduce the speed and fuel quantity, then points would arise when the engine runs clean. These limiting points of clean running are very important. If they are well up in the speed and load range then the engine can be classed as a good one and vice-versa if they are low in the appropriate ranges. Should there be no points of clean running on either range, then the engine is indeed a very poor one.

FIG. 1

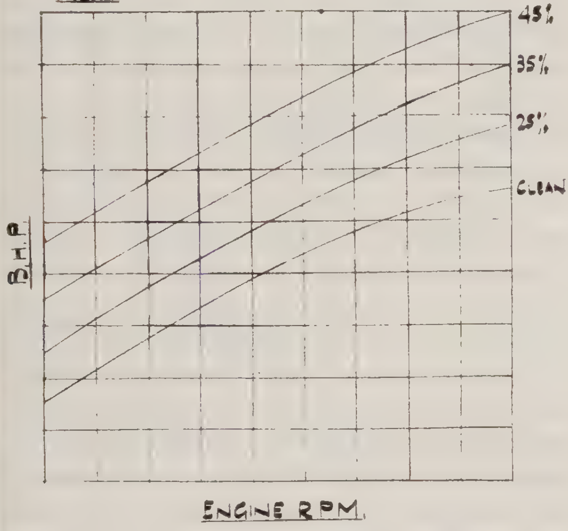
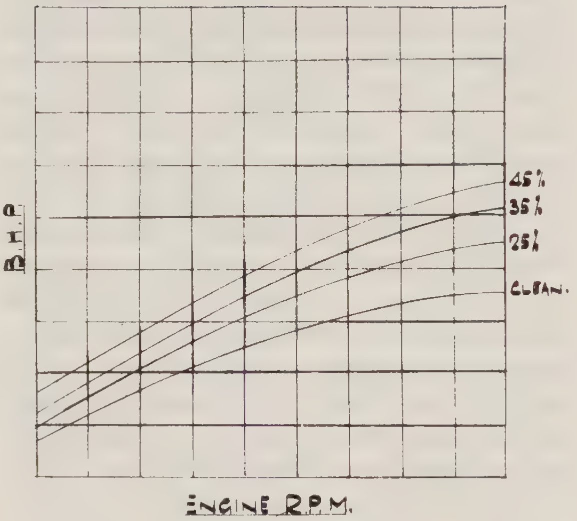


Figure 1 is a graph which endeavours to illustrate these points. Various horse power curves are taken over the speed range in which the throttle has been set to give a constant exhaust smoke emission on the smokemeter. The line of clean exhaust means that the engine runs clean under all conditions of operation beneath the line. It is well up in both the load and speed range, whilst any increases in fuel admission do not readily raise the exhaust emission from the engine. This means that the engine is flexible and can go a long way before the exhaust limits engine output. On the road, such an engine would continue to run with an acceptable exhaust for extensive mileages. On the other hand, the curves shown in Figure 2, where the lines of clean exhaust and dirty exhaust are packed close together, then that engine would be ready to emit smoke with very little deterioration through running and what is more would have poor performance even in the new condition. Naturally, the manufacturer wishes to cover as much clean running range as possible with his engine, but can considerably widen its scope by permitting a small acceptable amount of exhaust smoke. The question now is what is an " acceptable exhaust "? Certain manufacturers permit a " trace," or " just visible " or even " moderate smoke," but whatever convention is used, a proper definition is lacking. With the smokemeter however there is no guesswork, and for new engines a 25 per cent. maximum light obscuration by the exhaust smoke through the Hartridge-BP meter would be a top limit. A " warning " upper limit for vehicles on the road would be approximately 45 per cent., whilst 60 per cent. would be a condemnation limit. It is known, of course, that as engines wear out and fuel injection equipment goes off tune, the exhaust emission becomes greater and the difference between 25 and 45 per cent. is the allowance made to cover general service deterioration. The 45 per cent. may only occur at the maximum speed of the engine; nevertheless this is considered a reasonable figure indicating that the engine requires some maintenance attention.

FIG. 2



Let us consider the factors which cause exhaust smoke during the operation of the vehicle on the road. Assuming that the engine left the maker in an acceptable condition, but the exhaust emission has deteriorated with time, the simple conclusion is that engine combustion has been upset. Three main things could have gone wrong either singly or collectively to bring about this state of affairs. These are fuel injection equipment, engine cylinder compression and interference with the air breathing of the engine. Fuel injection equipment embraces injectors, injection pump, engine governor and fuel oil filters. All these are items of precision manufacture. Small things can easily unfavourably disturb this equipment and if we take the injectors alone, such things as:

Leaky needle valve seats,
Tight or sticky needle valves,
Blocked or partially blocked fuel orifices,
Reduction of fuel release pressure causing poor atomization, can all bring about a foul exhaust.

Even the fitting or the clamping of the injector in the cylinder head if not carried out correctly can mar its operation.

In the case of the fuel injection pump, it is essential that all pumping elements must deliver reasonably the same quantity of fuel otherwise certain engine cylinders will be overworking causing smoke while others will be slacking and not doing a fair share of the work even though the total engine output is what it should be. The pump must also be calibrated or set correctly for maximum fuel delivery otherwise if all the pumping elements are overfuelling then the exhaust smoke could be intolerable. It is not unknown for operators deliberately to overfuel the engine for the sake of obtaining greater power output; the result of this operation generally results in excessive exhaust output. The fuel pump has also to be correctly timed against the engine crankshaft and here again mistiming, especially if on the late side, leads to a polluted exhaust. There is still another malady which upsets the engine and consequently the exhaust to a very high degree and that is sticky fuel pump delivery valves. If the delivery valves stick or are sluggish in operation, an excessive quantity of fuel passes the injector because the valves fail to unload or return from the pipe line to the pump a definite quantity of fuel which otherwise it should normally do for correct engine operation.

It may have been gathered from these comments that dirt and foreign matter can cause the majority of ailments leading to bad fuel injection and consequently bad exhaust. It is, therefore, essential that the fuel filters must have proper and regular maintenance in order to protect the remainder of the injection equipment and preserve good clean engine running. The makers' recommended filtration elements should always be used and the actual replacement of the elements must be carried out with hygienic precautions to avoid foreign matter entering the filter during the replacement process.

As a rule fuel pumps are equipped with an excess fuel device provided for aiding a quick start in low temperature conditions. This device is sometimes abused by unconcerned operators or drivers as a means of increasing engine power by permanently engaging or devising means to operate at will the excess fuel device in order to increase the range of pump control rod movement, and hence pump output. This device can admit anything from 25 to 100 per cent. extra fuel over and above the engine's normal ration, and it takes very little imagination to realize that the exhaust under these conditions would be deplorable. In recent times this device has been designed so as to baulk this form of tampering but there are still numerous vehicles on the road capable of being severely abused by " rogue " operators. As mentioned earlier, another form of smoke creation is to over-speed the engine. A governor is usually fitted to the diesel engine which has been carefully set to a stipulated maximum speed by the engine builder. If for the sake of increasing the speed of the vehicle, the governor adjustments have been disturbed towards the higher speed condition, then the engine will emit smoke in greater quantities than was ever intended. Such over-speeding is not always deliberately produced and can be caused by the inattention to the correction of worn governor parts if of the mechanical type, or air leaks, etc., if they are of the vacuum type, or worn adjusting points in the hydraulic form of governor.

Finally since we are dealing with compression ignition engines, it follows that if there is no compression there is no ignition, or if poor compression, very poor ignition or combustion. It is essential, therefore, that cylinder compression must be maintained to its maximum value if the utmost efficiency is to be derived from the engine. To achieve this, cylinder wear must be carefully checked to ensure that piston rings have a good chance of doing their job. The rings must also be in first class condition, free from scuff marks, a perfect bed on the sides and face and the radial pressure must be within the makers' recommended tolerances. The pistons must also subscribe to good compression by being free from wear in the ring grooves and, at the same time, the rings must be free to work correctly in the grooves and no excessive wear should have taken place on the piston skirts or top lands. Inlet and exhaust valves must seat perfectly. Very often much damage is done by hand lapping and grinding valves just for the sake of doing it. The proper thing to do is to use a cylinder pressure gauge and if compression pressure falls below that recommended by the makers, then valves and the like must receive attention but it is unwise to disturb the valves, etc., if compression pressures and lubricating oil consumption figures are good.

The final point now is the condition of the air intake or breathing of the engine. By this is meant items such as inlet ports in the cylinder head, the inlet manifold with its throttle and venturi if the engine uses a vacuum governor, and the air filter. Any of these components can upset engine performance considerably if they become blocked with foreign matter, preventing the engine from breathing correctly and thus causing indigestion of the engine's fuel. The air filter should protect the remainder of the air intake system but often the filter is neglected which usually causes one of two things. Either the filter itself becomes choked through lack of cleaning and attention and tends to strangle the engine or else it is damaged internally and thus allowed to pass the dirt, etc., and then choke the remainder of the air system. The net results of either of these negligences is a smoky engine.

SOME FACTORS CONCERNING DIESEL ENGINE EXHAUST SMOKE

By

*J. K. Lock, B.Sc. (Eng.), D.L.C., G.I.Mech.E., A.F.Inst.P.**

Summary

The paper considers the possible reasons for the emission of black exhaust smoke from automobile diesel engines. The principal reasons are [1] too great a quantity of fuel being delivered by the high pressure pump into the engine, or [2] malfunctioning of the fuel injectors. Evidence of the effect of these factors on exhaust smoke is presented. Both of these factors are thought to be due to poor maintenance, particularly of the fuel injection equipment.

Investigations have been carried out into the effect of changes in fuel quality on exhaust smoke, and it is shown that while large changes in fuel quality can produce small changes in exhaust, the changes permissible within the acceptable marketing specification are only small. The effect of mechanical factors discussed above is of greater importance.

Introduction

IT is a common experience that there are a number of diesel engined vehicles on our roads which emit black smoke and it is the author's intention to discuss the likely reasons for this smoke.

Production of Black Smoke

In the diesel engine, there is generally no throttle between the atmosphere and the engine cylinders, so that an almost complete cylinder full of air is available for each combustion cycle. Power output is regulated by the quantity of fuel that is injected into the cylinders. (This is in contrast to the petrol engine, in which the petrol is mixed with the air in an almost constant ratio outside the cylinders, and only sufficient of this mixture to develop the power required is drawn into the cylinders for burning).

When the power output of the diesel engine is low, there is far more air (oxygen) available in the cylinders than is required to burn the small quantity of fuel injected, but as the power output increases, the quantity of excess oxygen becomes progressively smaller. If the quantity of fuel is increased to the stage where some of the fuel is unable to find sufficient oxygen to burn completely, then partly burned fuel in the form of carbon is emitted with the exhaust gases, and this, very largely, is what constitutes black smoke.

Effect of Overfuelling

Figure 1 shows how a typical automotive single-cylinder diesel engine in good mechanical condition responds to variations in the quantity of fuel injected. Up to approximately 4 lb./hr., engine power increases almost linearly with fuel input, and there is virtually

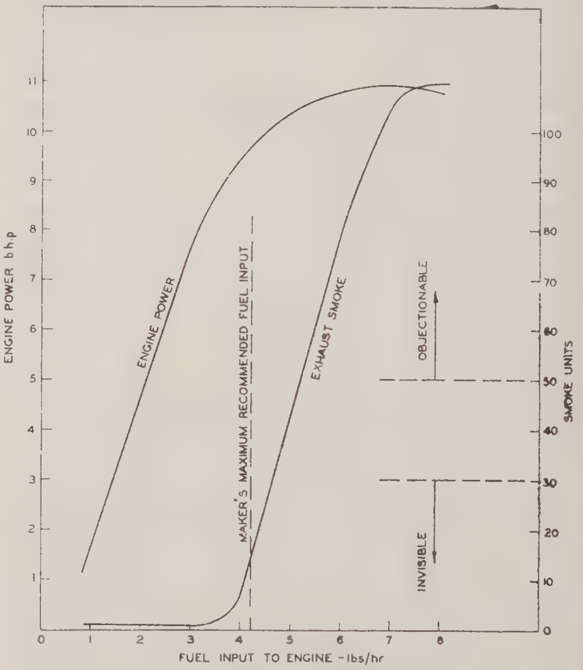


FIG. 1 EFFECT OF FUEL INPUT ON POWER AND EXHAUST SMOKE

no exhaust smoke. Increasing the fuel flow above 4 lb./hr. causes a rapid increase in smoke and a marked reduction in the rate of power increase. The results shown were all obtained at a constant speed, but the same picture would have been obtained had any other speed been chosen from the working range of the engine.

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* Engineer, BP Research Centre, British Petroleum Company Limited.

The smoke readings shown on this and other figures were obtained using a Hartridge-BP Smokemeter*. The experience of the author has been that for conventional diesel engines in heavy commercial vehicles, below 30 smoke units the exhaust is invisible under most conditions, and above 50 units the exhaust starts to become objectionable.

All diesel engines are fitted with a stop to limit the maximum quantity of fuel used by the engine (in the case of the engine discussed above, the limit specified by the manufacturers is 4·2 lb./hr.) and almost always the exhaust smoke at this limit is invisible.

Exhaust smoke can be caused by increasing the fuel flow beyond the limit specified by the engine manufacturers. It will be seen from Figure 1 that this results in a slight increase in power, but is accompanied by an increase in smoke. It is thought however that the habit of deliberately increasing the fuel input to obtain more power is not as common as it used to be.

It is not sufficiently realized however that this extra power is purchased at an unduly high increase in fuel consumption. Table 1 compares the increase in fuel input beyond the limit set by the engine manufacturers with the corresponding increase in power.

Another possible cause of overfuelling is wear of the maximum fuel stop. If the exhaust is of borderline visibility with the normal maximum fuel input, even a slight increase in fuel input can result in a disproportionate increase in exhaust smoke.

Table 1

Effect of Increasing Fuel Consumption Beyond Maker's Maximum Limit

Percentage Increase in Fuel Consumption	*Percentage Increase in Power*
5	2
10	3·7
15	5·5
20	7·0

There is one case where a very large increase in exhaust smoke can be obtained from an engine in good condition. In cold weather, diesel engines start more easily if, while the engine is cranked, the quantity of fuel delivered to the engine is greatly in excess of the normal maximum. Diesel engines therefore have an excess fuel device which permits the fuel input to be increased by up to 100 per cent. beyond the normal limit. Generally the design of this device is such that it automatically ceases to operate once the engine starts, but irresponsible drivers have been known to arrange systems of wires and string so that the device can be put into operation when maximum power is required. This causes very dense smoke to be emitted, so much of the blame placed on the diesel engine as a contributor to air pollution has been caused by the comparatively few drivers who misguidedly indulge in this bad practice.

Effect of Injector Deterioration

So far, overfuelling has been discussed on the assumption that the engine generally is in first-class order.

The time available for combustion in a high speed diesel engine is very small (approximately three milliseconds in a typical heavy vehicle engine at full speed) and if the fuel is to be completely burned in this time, the oxygen must be immediately available to the fuel; this is achieved by injecting the fuel in a very fine spray.

It is no exaggeration to say that the one factor which influences smoke formation more than any other in the

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* A photograph of this smokemeter is shown on page 34.

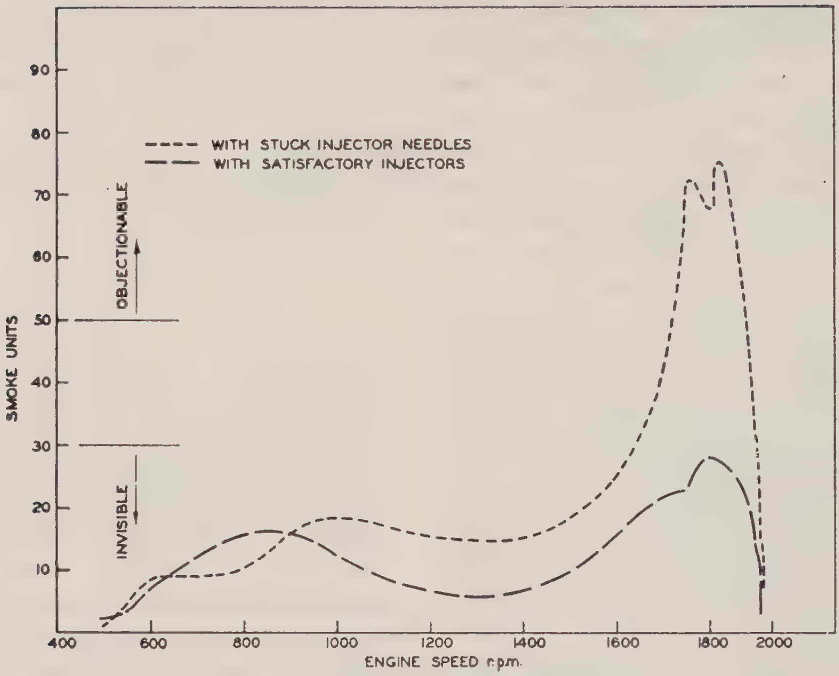


FIG 2 EFFECT OF NEEDLE STICKING

diesel engine is the condition of the fuel injectors. These injectors are robust items of equipment that will operate satisfactorily for many thousands of miles without deterioration, but in order to achieve this, the injectors require to be serviced regularly and with due care.

1. *Sticking Needles*

One of the commonest faults with injectors is that of sticking needles, which cause a very coarse spray to be formed at the start and end of the injection period and give rise to exhaust smoke. The reason for sticking injector needles is almost invariably dirt. The clearances between the needle and the injector body are of the order of two microns (25 microns are equal to 0·001 inch) and it is imperative that during the overhaul of the injectors, absolute cleanliness is necessary to avoid dirt causing binding of the injector needle in its body. Again, although fuel is delivered to the vehicles in a clean state, the fuel tanks of vehicles can contain dirt and scale and adequate fuel filtration is vital. The paper fuel filters that have become available during the last few years have helped considerably in reducing the frequency of dirt entering the fuel system. Again, unless care is exercised by the fitter responsible for routine injector and filter change and fitting, dirt can enter the fuel system during this servicing and can undo the good achieved by first class injector overhaul and by the provision of the finest filters.

Figure 2 shows results from an automotive diesel engine illustrating the effect of sticking needles. These curves were obtained during road testing of a commercial vehicle and show the smoke readings observed during a full torque acceleration (i.e. with accelerator pedal fully depressed). In this case, the incidence of sticking needles was traced to dirt entering the fuel system between the filters and the injection equipment.

2. *Hole Blockage*

In the injectors, the fuel is sprayed through holes 0·010 to 0·015 inch diameter; sometimes these small holes become blocked with carbon and this leads to local overfuelling in the combustion chamber and to exhaust smoke. Engines seem to vary in their response to hole blockage, but in some engines one blocked hole results in a large increase in smoke.

Figure 3 shows the effect of one blocked hole in a small single cylinder stationary diesel engine. It will be seen

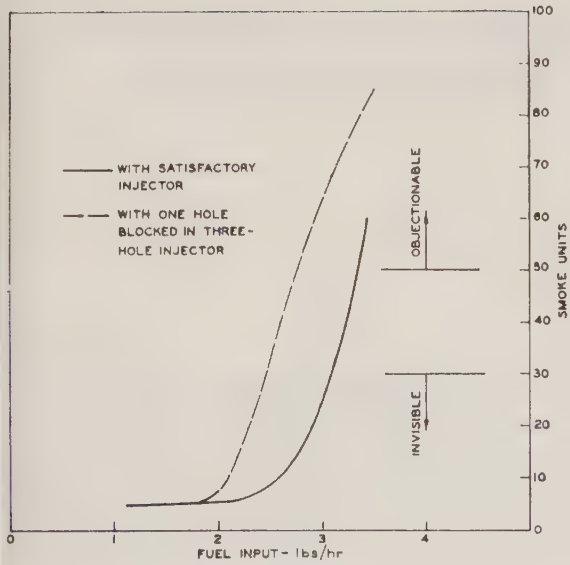


FIG. 3. EFFECT OF INJECTOR HOLE BLOCKAGE ON EXHAUST SMOKE

that not only is the smoke more dense at full fuel input, but the exhaust smoke is visible for a significant part of the range of fuel input.

One of the principal reasons for hole blockage is needle sticking which, as explained above, is caused by dirt in the fuel system. Hence there is again further reason for care in ensuring the highest standards of fuel cleanliness.

In the experience of the author, the reasons for exhaust smoke described above cover most of the cases of excessive smoke that he has investigated. There are other possible reasons, such as blocked air filters, incorrect fuel timing etc., but their frequency of occurrence is much smaller.

Effect of Fuel Quality on Exhaust Smoke

Work has been done to assess the effect of changes in fuel quality on exhaust smoke and some of these results are given in Figures 4 and 5. These results were obtained during the road testing of two different makes of heavy commercial vehicles and they represent smoke readings obtained during full torque accelerations with the engines using a range of fuels. It is of interest to note that with the vehicle, the results of which are shown on Figure 4, at the maker's recommended limit of fuel input, the exhaust smoke was barely measurable, even with the Hartridge-BP smokemeter. The results shown were obtained by deliberately altering the maximum fuel stop to give 30 per cent. excess fuel.

In both engines, kerosine produced less smoke than the other fuels, but with this exception, the effect of fuel quality on exhaust smoke was small.

The smaller level of smoke with kerosine is ascribed in part to the difference in specific gravity between

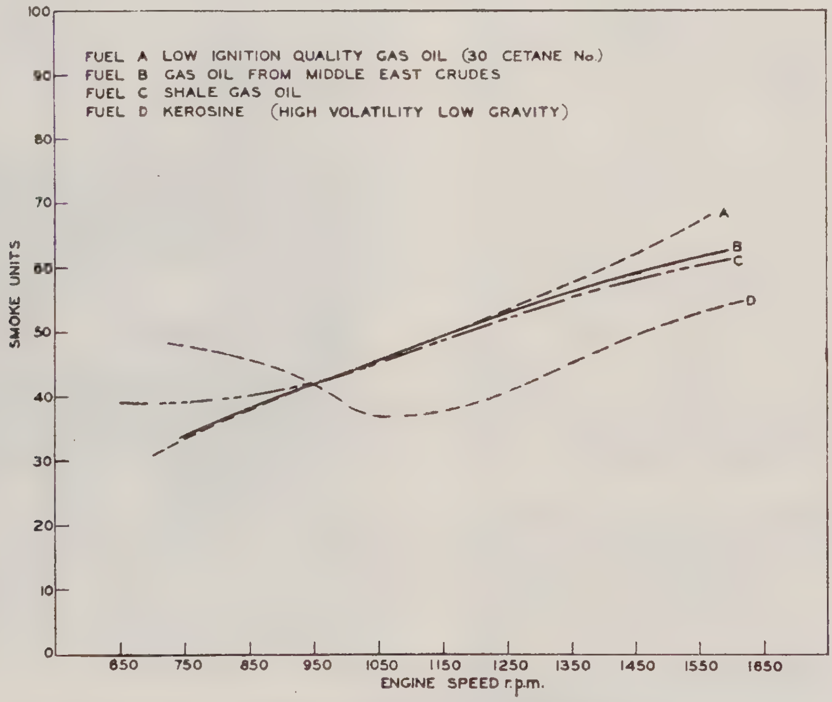


FIG. 4 EFFECT OF FUEL QUALITY ON EXHAUST SMOKE

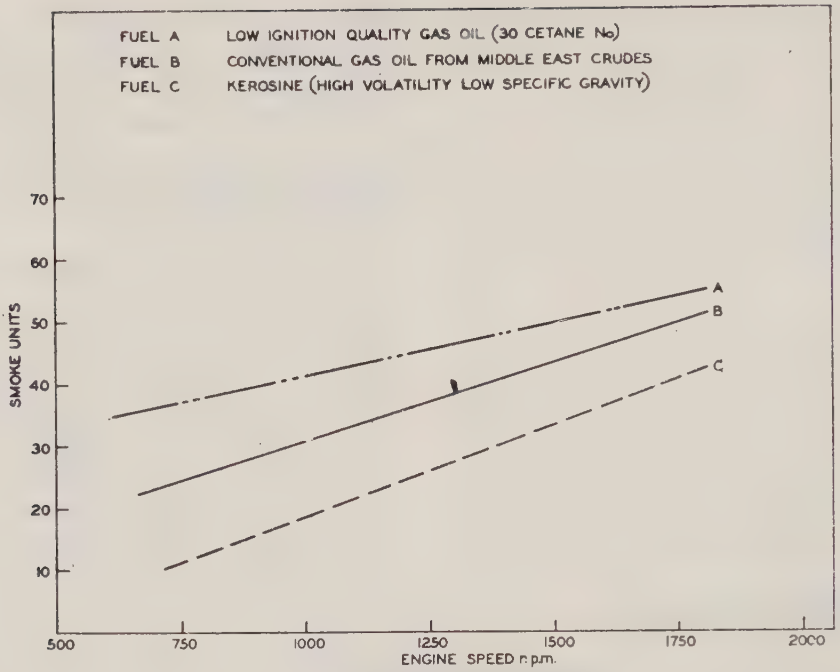


FIG. 5 EFFECT OF FUEL QUALITY ON EXHAUST SMOKE

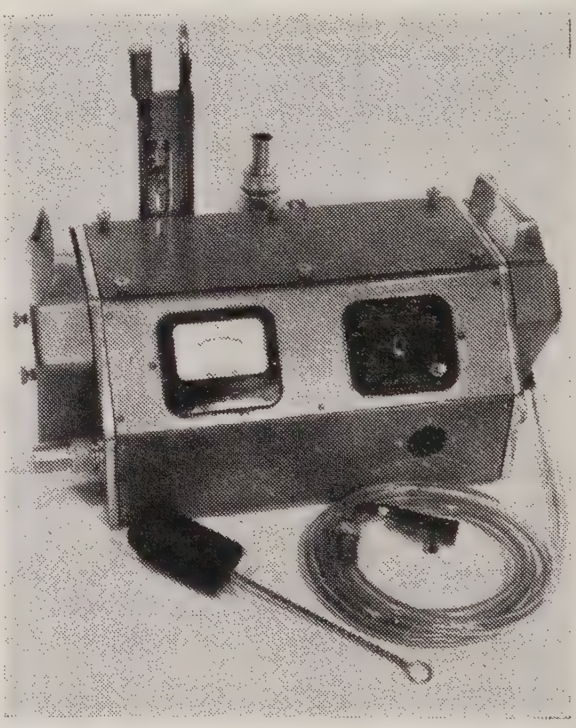
this fuel and the remainder. The diesel engine injection pump delivers a fixed volume of fuel to the engine and therefore, with kerosine, a smaller weight of fuel is injected than with the other fuels. If the maximum fuel stops had been adjusted with kerosine to deliver the same weight of fuel that was obtained with the other fuels, then the difference in smoke levels would have been smaller. Since less weight of fuel was injected with the kerosine, it follows that the horsepower would have been correspondingly reduced.

It will be seen (Figure 4) that the kerosine produced an increase in smoke at low speeds in one of the engines. This is thought to be due to the lower viscosity and density of the kerosine producing under-penetration at low speeds, due to too little turbulence in the combustion chamber. As the speed rose, the increased turbulence offset the effect of the under-penetration.

The variation in quality of the fuels used in this work was much greater than would be allowed by modern specifications of diesel fuel in this country. It can be said therefore that within the range of quality variations encountered in the market, the effect of fuel quality on exhaust smoke is small.

Acknowledgement

The author wishes to thank The Chairman and Directors of The British Petroleum Company Limited for permission to publish this paper.



The Hartridge–B.P. Smokemeter

METHODS OF REMOVING SMOKE FROM THE EXHAUST GASES OF DIESEL ENGINES

By

*L. E. Reed and S. C. Wallin**

Summary

The diesel engine, despite its efficiency, has a reputation for being a source of one of the worst forms of pollution, because of its emission of black smoke, formed by unburnt fuel. Most of the emission is a result of such factors as poor maintenance, but if a device could be found to prevent smoke being emitted, it would make a useful contribution to the reduction of air pollution. Cyclone cleaners, combustion (either catalytic or non-catalytic), filtration and scrubbing, were considered as means of removing smoke from exhaust gases, and experimental work was carried out on some of them. A single-cylinder stationary engine and a six-cylinder engine in a 10-ton vehicle were used for the experiments. Cyclones were not experimented with, as their efficiency is extremely low with small particles as found in diesel smoke. Non-catalytic combustion needed too high a temperature and catalytic combustion was ineffective. No suitable filtering medium could be found, nor could any effective scrubbing device. All methods which were capable of effecting a substantial reduction would be costly in operation, and none are considered satisfactory for road transport. It is concluded that more emphasis should be given to the prevention of smoke than to devising methods of removing it.

Introduction

Of the modern methods of producing mechanical power the diesel engine is probably the most efficient and among the most reliable. For these reasons its application to motor transport was obvious and its position as basic prime mover is well established. It is unfortunate that in spite of its superior efficiency it makes a noticeable contribution to the air pollution of cities and arterial roads. Its reputation of being the source of one of the worst forms of pollution is entirely due to the fact that the diesel engine can emit black smoke, formed by the incomplete combustion of the fuel. The exhaust from the petrol engine on the other hand may contain a much higher percentage of partially burnt fuel, but is invisible.

There are many reasons why a diesel engine may produce smoke[1]; it may be due to poor maintenance, particularly of the injectors, low compression ratio, partly blocked air intake filter, or it may be produced by overfuelling. This latter condition occurs during periods of acceleration when the engine is running below the governed speed or it may be achieved deliberately to obtain extra power when the engine is under heavy load. Most of the black smoke produced by diesel engines is a result of overfuelling.

Although black smoke should not be produced, the fact remains that many diesel lorries on the road emit smoke, and some emit a great deal and while it is not suggested that any device should replace the need for correct servicing and operation of diesel engines, if a simple device could be found which would prevent this it could make a useful contribution to the reduction of air pollution.

The requirements of any device to reduce smoke are that it should be cheap, be foolproof, have a long life, be robust, require little maintenance and should not reduce the performance of the engine appreciably.

Nature of the Problem

The smoke in the exhaust exists as small particles of higher hydrocarbons or other carbonaceous substances in the

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* Warren Spring Laboratory, D.S.I.R.

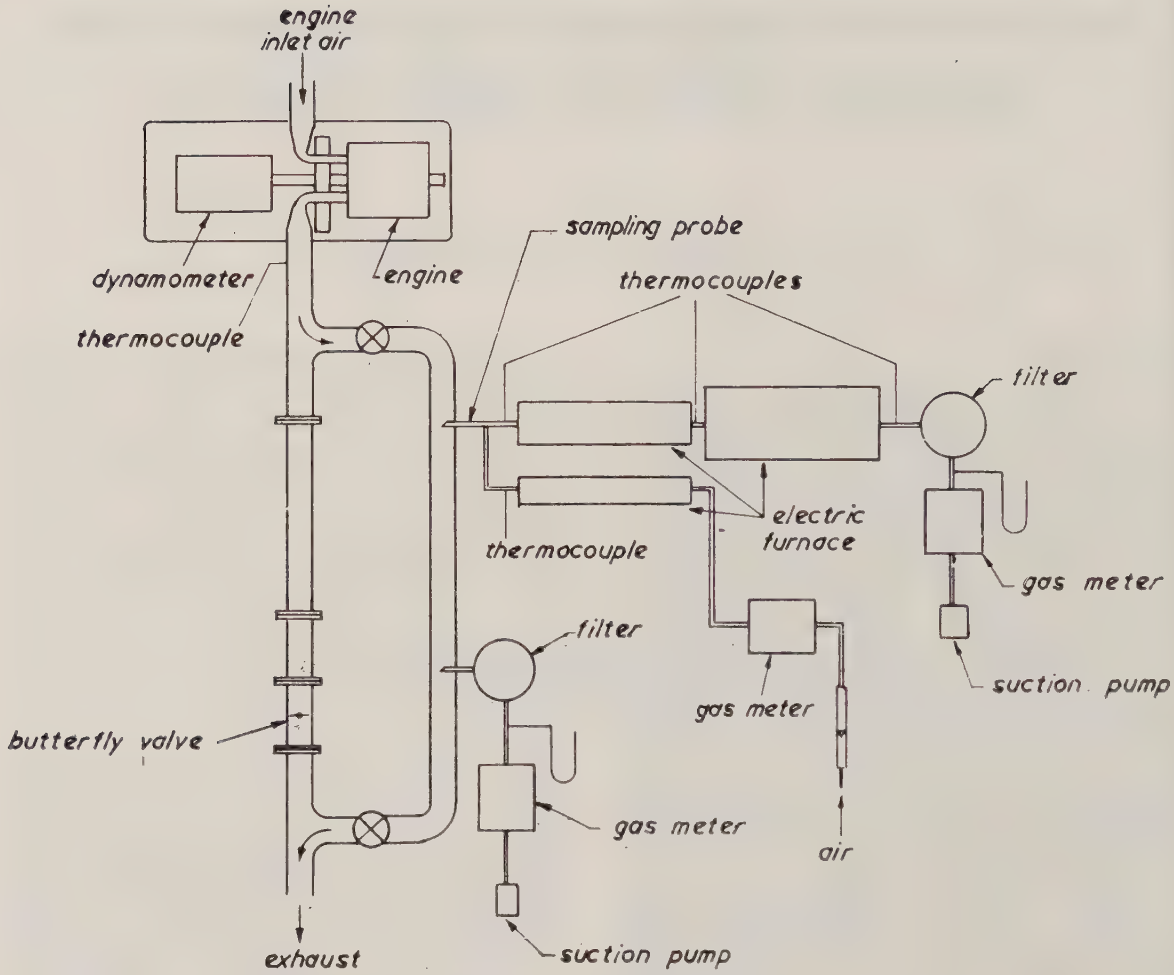

Fig. 1. Diagrammatic arrangement of smoke burning apparatus

size range from 0 to 1 micron[2]. The quantity of smoke depends almost entirely upon the condition of operation, but a typical black smoke will contain 1·6 g/cu.m of soot which is equivalent to 2 per cent. of the fuel burned: for comparison, it is estimated that to avoid visible nuisance the concentration should not exceed 0·35 g/cu.m[3]. Black smoke will be accompanied by combustible gases which may represent a loss of a further 7 per cent. A large vehicle operating for 40 hours per week and emitting black smoke for five minutes every hour emits a total weight of 2·5 kg. soot. This would occupy a volume of about 0·057 cu.m (2 cu. ft.) is separated and allowed to settle.

Methods of Removing Smoke

There are many well known methods of removing particulate matter from a gas stream, including the use of cyclone cleaners, combustion (either catalytic or non-catalytic), filtration or scrubbing. All of these methods have been considered and experimental work has been carried out on some of them.

Equipment Used

Two engines were used for experimental purposes; they were a single-cylinder, stationary engine and a six-cylinder engine in a large 10-ton vehicle.

The single-cylinder engine, a diagrammatic layout of which is shown in Figure 1, was fitted with a water brake so that the engine could be loaded, and by increasing the fuel supply the concentration of soot in the exhaust smoke could be adjusted to any desired value. Normally conditions were set to give a figure of about 1·4 g/cu.m. The exhaust line was fitted with various tappings so that

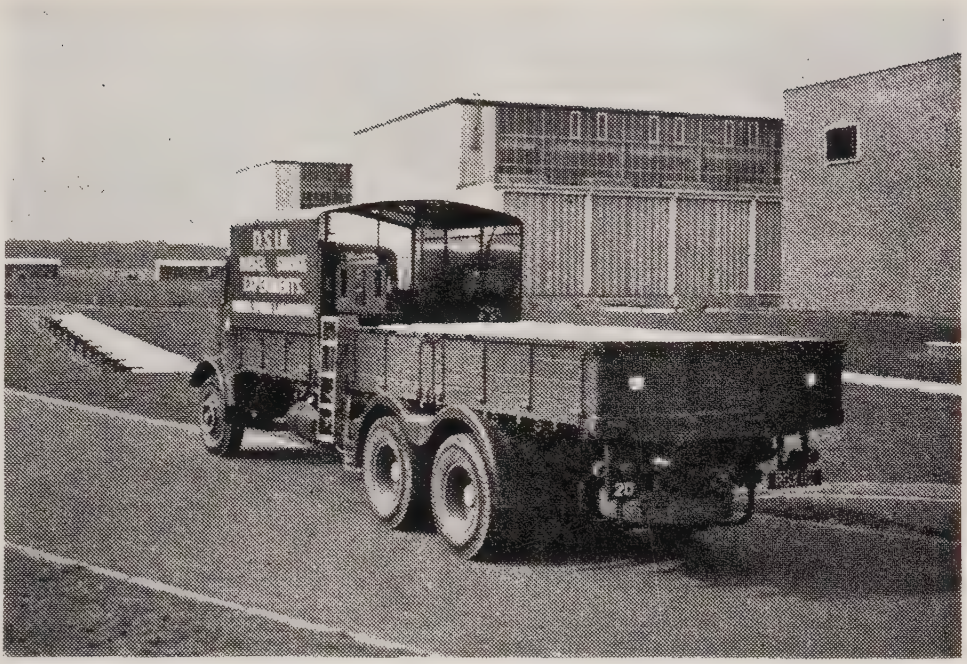

Plate 1. Diesel Test Lorry

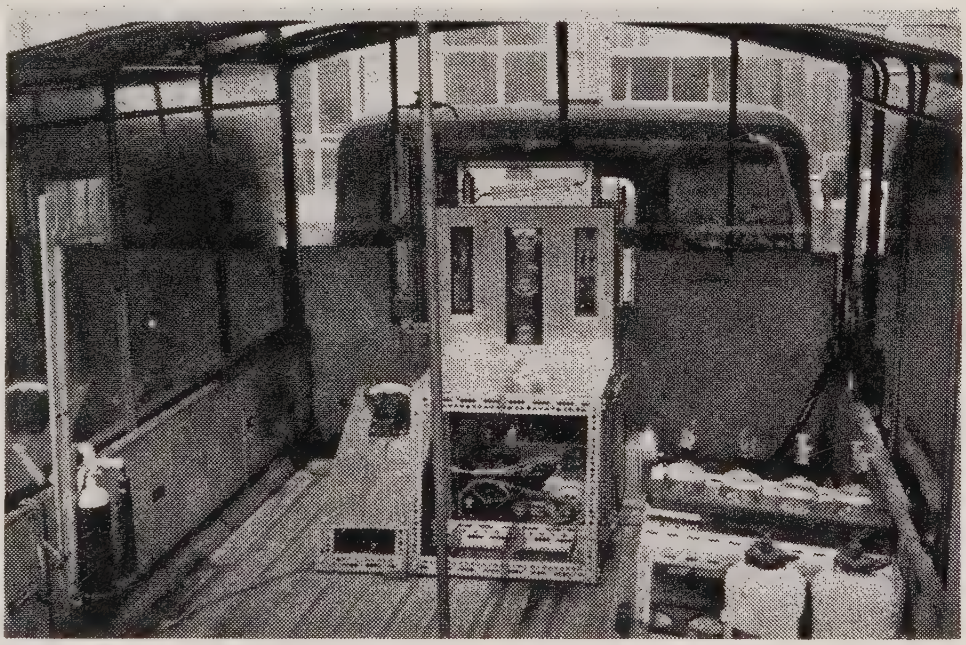

Plate 2. Inside of lorry showing instrumentation

samples could be extracted as required and with thermocouples which gave direct readings of the gas temperature at various points.

The large vehicle was used " on the road " to test filters of proprietary manufacture and it was instrumented so that the concentrations of soot in the exhaust, the fuel consumption and gas temperature could be determined, and provision was made for extracting gas samples for subsequent analysis. Details of the lorry and instruments can be seen in Plates 1 and 2.

Results

1. *Cyclones*

The efficiency of cyclones falls off rapidly as the size of the particle decreases and when the size is less than two to three microns the efficiency is very low. As the size of the diesel smoke particles is less than one micron the possibility of a cyclone collecting a reasonable percentage is remote and therefore no experimental work has been carried out on this method of cleaning.

2. *Combustion*

(*a*) *Non-catalytic combustion*

The best method of removing the smoke is to burn it as the products of combustion are gaseous and innocuous and there is no solid residue to be disposed of. A small apparatus was made in which a sample of exhaust gas was passed through a metal tube heated by two furnaces in series. The first furnace preheated the gas to 520°C. and in the second furnace the gas was raised to a higher controlled temperature. A supply of preheated air, amounting to 25 per cent. of the gas flow was fed into the gas stream before the two furnaces to ensure that there was sufficient oxygen present for combustion. The gas and air mixture was passed through the heated tube at a velocity of 0·6 m/sec. (measured cold). Figure 2 shows the efficiency of combustion at different temperatures of the exhaust gas. Below a temperature of about 600°C. the efficiency of combustion of smoke is low, but it increases rapidly as the temperature is increased. A temperature of at least 800°C. would be required to give a sufficient removal of soot to make the exhaust " unobjectionable." To give some idea of the impracticability of applying such a system to a vehicle, the energy required to heat the exhaust from its outlet temperature of 520°C. to the figure of 800°C. is 27 kw which is equivalent to 11 per cent. of the fuel burnt.

(*b*) *Catalytic combustion*

Since straight combustion of the smoke, although possible, appears to be unattractive because of the high temperature necessary the possibility of burning the gases at a lower temperature by the use of a catalyst was examined. This method is employed in devices developed in America for use on petrol engines. Using the same type of apparatus but dispensing with the preheating furnace a number of different catalysts were tried including a mixture of manganese and copper oxides deposited on alumina, cobalt oxide supported on silica brick, platinum deposited on silica brick, and cobalt and chromium oxides deposited on alumina. The temperature of the exhaust gas supplied to the catalyst was of the order of 500°C. to 550°C. after a small quantity of air had been added.

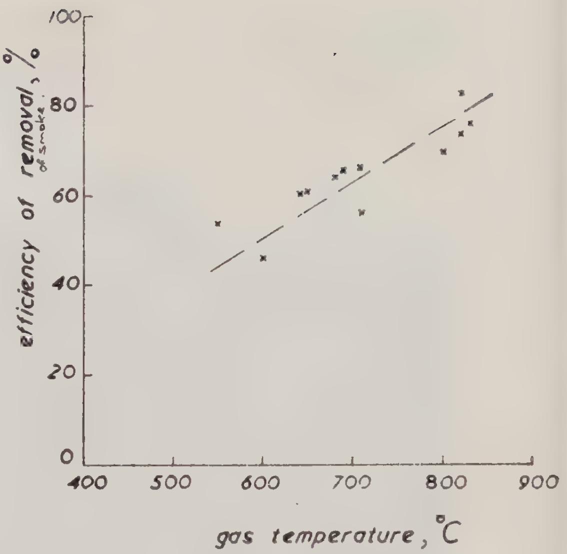

Fig. 2. Influence of temperature upon efficiency of removal of smoke

With the cobalt oxides 85 per cent. of the smoke was removed, but it was found that approximately half of this was oxidized and the other half had been retained by the catalyst. All the other catalysts filtered out a certain amount of the smoke and none oxidized more than about 40 per cent. of it.

These tests indicated that catalytic combustion of smoke at the temperatures encountered in the exhaust was not likely to be successful.

3. *Filtration*

The possibilities of removing the smoke from the exhaust gas by filtration have been considered and a number of types of filtering media have been tested.

With pads of fibrous material it was possible to remove a high percentage of the soot but the material quickly became clogged and often disintegrated under the vibration. No medium tested has proved satisfactory for application to vehicles and until one is available that will satisfy most of the requirements, i.e. mechanical robustness, resistance to temperature, ease of cleaning or cheapness in replacing, low resistance to gas flow and smallness in size, the prospects of economic filtration are remote.

4. *Scrubbers*

Scrubbers for removing the pollutants from diesel exhausts have received a great deal of attention although they are considered to be more efficient in the removal of some of the gaseous constituents[4] than the solid pollutants. One scrubbing device which was designed to retain solid particles has been tested on the diesel test vehicle. The device contains oil as the scrubbing medium. The efficiency of removal of smoke was low and under extreme conditions when the exhaust temperature was high the loss of oil from the scrubber was excessive.

Conclusions

All the methods which have been suggested for removing smoke from the exhaust of diesel engines have been considered, and those which were thought to show some promise have been studied experimentally. All the methods which are capable of effecting a substantial reduction would be costly in operation, and none is considered to be satisfactory for application to road transport. It would appear that more emphasis should be given to the prevention of smoke rather than to devising methods of removing it once it has been formed.

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Discussion

J. R. Archer-Burton, (Chief Constable for the North Riding of Yorkshire), opening the discussion from the platform, said that he was the " simple soul " just referred to by Mr. Douglas Lister. He had noticed that he did not say " pure and simple." It was only as a result of the persuasive powers of the Chairman that he found himself quite unexpectedly on the top deck.

He had first become involved with this splendid Society when he had been invited to prepare a paper some years ago and one might say, for his sins here he was again! He felt that one should express an appreciation especially from their (the Police) point of view to Mr. Douglas Lister for that splendid paper he had presented so well. Personally speaking, he was very glad to see Mr. Lister's acknowledgment about the increased Police activity, so far as it affected this important business.

Their primary object was prevention, and a tremendous amount of work was done behind the scenes in that direction, so far as it affected smoke from vehicles, which he thought was appreciated by a large part of the motoring public. Prosecutions had been mentioned and he knew how keen the Society was about that side of it. He could only speak for his County when he said that there had been a very substantial increase in cases reported of that nature. It would be realized that there was hardly need for him to remind them that punishment was no concern of the Police. But enforcement was difficult with depleted forces as they could well imagine.

One more point was that of the question of training which he thought would interest the Conference. They had their driving schools throughout the country, but as far as this one was concerned in the north-east, he thought the Conference would be glad to know that Police were going to receive technical instruction in connection with brakes and steering and so forth.

R. Williams, (Coventry), said that he was particularly glad that this subject was being tackled at this Conference again. Wherever clean air was discussed in its wider spheres on the domestic or industrial front, every public health officer and local councillor was met with " we are for clean air but why don't you do something about diesel fumes." The Conference Session had had talk about experts from the platform and he was one of those people who believed there was something in Henry Ford's attitude to experts " God preserve me from the expert that says something can't be done." Delegates would remember that in Ford's particular instance it had been said by the experts that wind-screens could not be made in a continuous sheet, so he gave the job to two blokes who did not know it was impossible and got it done.

While Mr. Williams believed that all forms of air pollution should be tackled he questioned whether it was a fact that public health was menaced by diesel fumes. The last expert to speak had put that point too. Dr. Lawther of the Medical Research Council had said that there was not yet any real proof that diesel fumes did harm to health. There was no real proof that dirty cups and dirty crocks brought disease, but we knew that clean cups and clean crocks did not bring disease, so that whether we knew or not about diesel fumes creating health hazards he thought it was our purpose to take action in case they did and in any event there was ample grounds on safety and the pure fact that aesthetically we did not want filthy fumes. The Conference should not take up a platform from which it could be easily shifted on the health hazards. The speakers had given the Session, he thought, a very admirable review of the aspects of this particular problem, what he wanted to know was could they give a real standard? Once the standards were available manufacturers surely would themselves ensure that they were reached; operators would be aware that they had to maintain them.

The Society had done a great deal for clean air and he knew that it did not want to be left behind but be in the vanguard of any action taken in connection with diesel fumes. He saw that Lord Colwyn had formed a new organization to combat the harmful effects of diesel fumes, and this was known as Defume; that was a code name he understood for Diesel Exhaust Fume Abatement Society. That would interest him. The object of this association was to force Parliament and local authorities to take measures to put an end to the blight. As an officer of a local authority he wished to say that local authorities did not need forcing in the matter, he was getting a bit tired of the various societies and organizations always blaming the local authority. The Noise Abatement Society was not responsible for all the action taken to abate noise; local authorities would do the job if you gave them a legislative frame-work to do it with. He thought himself, as Public Health Inspector, that they must beware that they were not involved in something that was better done by somebody else. They could assist, they could help in every way, but he felt the Society must give a lead in this problem and Conference had the suggestion that testing stations should be set up where vehicles could be tested in the same way as the ten-year-old vehicle was being tested for safety; surely that was a very reasonable thing to do. He was not afraid of the local garages doing it to start with, anybody that could get a certificate which was then shown to be worthless would soon be put out of business, and it seemed to him that even on the local authority front, even the Association of Municipal Corporations, which Delegates would agree had a very jaundiced view about the activities of Public Health Inspectors, even they were not colour-blind enough to say that it was not something that pressure should be brought on Parliament for, and he hoped that the Conference would do everything they could to support the Clean Air Society in bringing about the necessary pressure on Parliament itself.

Miss Dorothy Boyd, (Individual Member), said the Conference had heard many experts on diesel fumes. She asked leave to introduce her own expert—her nose. Whatever the dangers to health from diesel fumes, her nose told her that they stank, moreover they stuck, as anyone would agree when cleaning a car exposed to them.

She, too, had heard Dr. Lawther's statement that the only means of traction acceptable in a coal mine in place of pit pony was a diesel engine. That, she thought, was a graphic argument for proper maintenance of diesel engines. She did not want to start a war of attrition. Whilst we had to live in peace with our motoring neighbours, there was need for action, and the problem was how to subdue those roaring Boanerges of the road to the docile inoffensive service of the pit pony. Both the police and local authorities were anxious to combat the danger of traffic fumes.

She thought that in the newly appointed traffic wardens there was the nucleus of a supplementary force to undertake that duty. At present, the function of the traffic wardens was to get the traffic moving. That object, once achieved, they were likely to get bored with so limited an outlook. So why should their duties not be extended to reporting offending vehicles? The method employed in Durban, South Africa, and commented upon in Mr. Lister's paper, seemed admirable since it dealt with offenders only, and so imposed the least possible restriction on road users as a whole.

A start could well be made on the Great North Road, where, under Highgate Archway, it often seemed that a goodly slice of the 1952 smog had been preserved in perpetuity.

R. E. Waller, (Medical Research Council), said that Mr. Lister had rightly pointed out that the visible smoke from diesel engines was only one aspect of the problem of pollution from motor vehicles. It was a grave and unnecessary nuisance in crowded streets and on busy trunk roads. Diesel smoke undoubtedly made a substantial contribution to the total pollution of the air in those environments and in some cases it created a real hazard to driving. He stressed however that there was no need to go beyond that. The case against diesel smoke was strong enough without invoking any specific effects on health, for as yet none had been demonstrated. The total amount of smoke from diesel engines was very small in comparison with that from coal fires, and in most localities it would be difficult to detect any effect of diesel engines. The MRC Air Pollution Research Unit used the Blackwall Tunnel as a locality polluted primarily by motor vehicles and even there their attention had to be limited to mid-summer days in order to avoid any effect of coal fires. They had shown a relationship between the concentration of smoke and the flow of diesel engined vehicles, and in this, petrol engined vehicles played little part. On the other hand the concentration of carbon monoxide in the tunnel had at all times borne an extremely close relationship to the density of petrol engined traffic, with diesel engined traffic playing no direct part in this. With about 1,000 petrol engined vehicles an hour and over 200 diesel engined vehicles passing through the tunnel they had found visibility seriously decreased by the smoke from the latter, but at the same time the carbon monoxide from the former had risen to several times the maximum allowable concentration.

Mr. Waller concluded by saying that he had introduced these results merely to show that pollution from diesel vehicles should not be considered in isolation from that of other motor vehicles.

Sir David Anderson, (Chairman, Clean Air Council for Scotland), thought there ought to be legislation making it compulsory for diesel road vehicles to discharge their exhaust vertically upwards. One could never count on having perfect vehicle maintenance and the number of vehicles on the road was increasing so quickly that improvements in engine performance would be more than counterbalanced by the growing volume of exhaust gases. Nothing should be left undone which would ameliorate the situation in any way and a vertical position for the exhaust could effect an immediate improvement on the air at breathing level on our roads.

An argument often advanced against vertical discharge of the exhaust from diesel road vehicles was that the fumes were heavier than air and would sink to ground level. This argument is based on a simple comparison of densities and is fallacious because it bears no relation to what happens in actual fact.

A mixture of gases of different densities does not separate out into layers according to density but mixes by diffusion, and this is what happens in the case of vehicle exhausts. The exhaust gases gradually disperse throughout the atmosphere and the main direction of diffusion is upwards. It would be, therefore, no more than common sense to give them a good start in the direction they must finally take.

Dr. C. O. S. Blyth Brooke, (Finsbury), said that at a conference held a few years ago, one of his colleagues, from (he believed) one of the northern towns, mentioned in the course of a discussion that he was regularly writing to the owners of diesel vehicles when it had been observed that they were emitting black fumes, and calling the attention of the owners to the nuisance that was caused in that way.

Since the beginning of 1958 Dr. Blyth Brooke had followed a similar procedure, and had been extremely gratified at the response he had received. This perhaps appeared to be contrary to the experience of Mr. Douglas Lister, who seemed to think that legal force was always necessary in order to get interest taken in the abatement of fumes. Dr. Blyth Brooke believed some other Medical Officers of Health had also adopted much the same course in seeking co-operation from the operators of vehicles. In many cases the owners of vehicles might not realize the need for the overhaul of their engine and that maintenance was not being carried out or that the drivers had disobeyed instructions with regard to the setting; it was therefore thought that the owners might welcome the information supplied which would help them to control their vehicles and their drivers more effectively.

Accordingly when any of the Finsbury Public Health Inspectors observed a vehicle disgorging black fumes, they noted the registration number of the vehicle and also, if possible, the name and address of the firm to whom it belonged. If it was impossible to obtain the latter information in this way it was obtained through the co-operation of the local taxation authority. He then wrote a standard letter pointing out to the owner that the Medical Officers of Health were much concerned at the present time with atmospheric pollution and calling their attention to the incident that had been reported to him and asking for full co-operation, going on to say " I am giving you this information in the hope that you will agree to co-operate with me to the extent of investigating the circumstances and taking such measures as may be deemed to you to be most expedient to prevent recurrence."

He had sent out, during the two and a half years which had succeeded that time, 71 letters of that character and he had received 43 answers, some of them in most lavish terms, expressing thanks for giving them the information and expressing assurance that the vehicles would be or had been checked, that was in 43 instances and in seven instances he had had a reply saying that the vehicles were regularly checked but that they were given an extra check on that occasion, in two cases he had had just a plain acknowledgment and in only 17 cases had he received no reply. It would seem therefore that out of the 71 nuisances that were observed, the procedure adopted led the owners to investigate carefully the conditions under which the offending vehicles were being operated, in all in 52 cases, and it might be assumed that in a high proportion of these instances it also led to a discontinuance of the nuisance earlier than otherwise would have been the case.

The action taken in a few boroughs could not, of course, have any significant effect on the prevalence of the nuisance generally, but Dr. Blyth Brooke suggested that if it were adopted throughout the country as a routine measure, the extent of atmospheric pollution of that type would be considerably reduced.

Mrs. C. M. Kerry, (The Women's Advisory Council on Solid Fuel) suggested that many women when on foot or in a following car, suffered great inconvenience or worse from black diesel fumes emitted by some road vehicles. She asked (*a*) could the police have wider powers to deal with offending vehicles as with cases of dangerous driving and (*b*) could the Society suggest any other form of prosecution which could be set in motion—apart from the action of police or private individuals—to rid the roads of this danger?

J. Maguire, (United Commercial Travellers' Association) referring to diesel fumes said that commercial travellers as a class, probably suffer most from this menace, and his Association was particularly involved because of the fact that more than 30,000 of the Association's membership of 35,000 were concerned as motorists, spending more than five days a week in all conditions of traffic and weather. On their behalf it was contended that the pollution of the atmosphere by diesel fumes and smoke was definitely harmful, not only to the driver's health and road safety, but also to the vehicle itself, the paintwork of which was bound to suffer.

In expressing appreciation of the scientific contents of the papers presented to Conference, the Association contended that prevention was better than cure.

The Association would continue to take joint consultative action, in which connection the co-operation of the Society was so beneficial, and through the medium of his activities as Parliamentary Agent, further Parliamentary questions would be raised from time to time through the medium of helpful Members of Parliament of all parties.

The urgency of the matter was shown by the fact that the Minister of Science replying to a question in the House on the 10th December last by Mr. Nabarro, explained that the Department of Scientific and Industrial Research was arranging to test two devices being developed in the United Kingdom and Switzerland.

The Association had now ascertained that the pursuit of the project for both devices had been discontinued on grounds of inadequacy on the one hand and expense on the other. Therefore, the Association asked—" Where do we go from there? "

The adjourned debate in which the Association had some part to play in the preparation, drew from the Minister a suggestion that the Regulations might perhaps be reviewed in the near future, and it was certainly proposed to press for such regulations which it was hoped would include new provision to discourage drivers of heavy goods vehicles from tampering with the excess fuel device on lorries and vans.

Finally, the Association contended that public opinion should be of such a degree as to regard diesel fumes and smoke being emitted from heavy vehicles, an offence, not only against regulations, but also against civilization.

P. Yorke, (Public Transport Association), said that his Association represented (exclusively) public service vehicles, that was to say, buses and coaches. He wished to make it quite clear they fully supported the objects of the Conference. They wanted to take every possible step to get rid of black smoke. A number of reasons why this was desirable had been put forward by previous speakers, with all of which his Association was in full sympathy, but he would like to add another, namely, that black smoke to a bus operator was appallingly expensive; even a tiny increase in fuel consumption per mile could cost a bus undertaking many thousands of pounds a year.

Mr. Yorke assured Mr. Lister that he need have no fear that there would be any " organized opposition " by operators. They wanted the law to be enforced. If in the odd case this entailed the prosecution of some black sheep in the bus industry maybe that was a good thing and helped to keep them on their toes.

Mr. Yorke mentioned that his Association had recently received from the Ministry the draft of a new regulation designed to prevent a driver, whilst in his cab, from activating any excess fuel starting device with the object of obtaining increased power. In other words, to make illegal the practice which had been mentioned by Mr. Waring and the last speaker. Mr. Yorke said that such practices were virtually unknown in the bus world, but if there *were* people who indulged in them they ought to be punished. Certainly his Association would not wish to oppose such a regulation.

He regretted that he had to criticize Mr. Lister's otherwise quite excellent speech in relation to the " census " he had put in so far as it related to public service vehicles. He was totally unable to accept the suggestion that 80 per cent. of exhausts from public service vehicles were " unclean "; this figure was absurdly high. He thought that the explanation was to be found later on in Mr. Lister's paper when he explained that 80 per cent. of the cases related to vehicles operated by the same undertaking. He did not know what his undertaking was, and hoped that it was not affiliated to his Association (!), but if its vehicles were really in the condition suggested it was quite unrepresentative of the industry. He asked if Mr. Lister could give a breakdown of the prosecutions mentioned in his paper showing what percentages related to public service vehicles.

Mr. Yorke said that he fully agreed with previous speakers that the fuel devices on a diesel engine were precision instruments, and that was why bus operators bought such elaborate and expensive equipment for servicing and inspection. A typical list of such equipment for a unit of 300 to 400 buses was:

	Cost
1. Electronic fuel pump tester	About £500
2. Optical equipment for inspection of wearing parts	100
3. Injector testing gear	25
4. Special vices for holding pumps for examination from all angles—3 at £15	45
5. Universal grinding and lapping machine	300
6. High-intensity lighting for inspection	50
N.B. This equipment must be used in a specially finished dust free room with tiled walls and floors, all of which can only be provided at considerable cost, say	1,000
	£2,000

He hoped this would emphasize the great importance attached by his members to maintaining the highest standards of maintenance.

In conclusion, he repeated that the bus industry was wholeheartedly behind the objects of the Conference and wished it every success.

Dr. A. Parker, (Royal Society of Health), said that it had been established that there was no need for the undue emission of smoke from the diesel engines of road vehicles provided that the engines were maintained in good condition and were not overloaded and there was no unauthorised interference with the rate of fuel supply. Unfortunately, the engines were often overloaded, particularly on steep hills. To increase power, though at a reduced efficiency of utilization of the fuel, some drivers wrongly increased the fuel to air ratio. In London, the diesel engines of the buses, which had to be operated under the difficult conditions of stopping and starting, emitted very little smoke because the engines were well maintained and were ordinarily not operated at over 90 per cent. of their rating.

The methods so far tried for burning the combustible gases and smoke in the exhaust gases from petrol engines and diesel engines were in his (Dr. Parker's) opinion not the right way of tackling the problem. After-burning of this kind represented a waste of energy that should be developed in the engine. With a well maintained and properly operated diesel engine, combustion should be practically complete in the engine. This was not the position with petrol engines and there was need for intensive research and development work with the object of developing petrol engines that would achieve complete combustion, while maintaining flexibility in operation, good acceleration characteristics, and a low weight to power ratio.

With regard to the detection of offending vehicles on the road, the method adopted by the Air Pollution Control Authority in the County of Los Angeles in California was interesting. There were labelled official cars driven by officers in uniform, who had police powers in relation to air pollution. The exhausts of diesel vehicles in that area normally discharged the waste gases vertically upwards above the vehicle. When a patrol officer in his car saw a vehicle emitting undue quantities of smoke, he followed the vehicle and after the emission had continued for three minutes he took a photograph with a special camera in which the picture could be completed as a print in one minute. The officer then stopped the offending vehicle and developed the photograph in the presence of the driver to show the undue emission of smoke. The officer then handed a " ticket " to the driver, who had to appear in Court. There were many prosecutions and in more than 90 per cent. of the cases there were convictions and fines. He, Dr. Parker, had seen the system in operation, but he doubted whether it would be acceptable to the people of Great Britain.

J. T. Turner, (Chairman of the Vehicles Committee, National Road Transport Federation and National Vice-Chairman, Road Haulage Association), agreed that there were culprits who emitted black smoke from their vehicles but expressed the view that he could not agree with the figure of ·25 per cent. that had been suggested but thought that 1 per cent. of the vehicles was nearer the truth.

He called the attention of the Conference to the fact that at no time had the Federation been asked to co-operate in abating this particular nuisance and he took the opportunity to extend an invitation for such co-operation. He stated that the public were the operators' customers and, naturally, they would do everything possible to avoid upsetting their customers in respect of charging high rates, poor service or even the emission of black smoke from their vehicles. He called attention to the growth of diesel engined vehicles stating that in 1935 there were only 10,000 diesel engined vehicles in use in Great Britain and the last available figure for 1959 was 315,639. He further stated that the growth of the use of diesel engines had out-paced the training of mechanics and that the available force of trained mechanics had not risen with the same speed. The Federation and its constituent associations had done much to combat this particular nuisance, he added they had had frequent consultations with the Society of Motor Manufacturers and Traders, and had asked the manufacturers and the Ministry of Transport to move the easy starting device out of the driver's reach when driving on the road. The Ministry of Transport had agreed and had drafted a Regulation on these lines which had been sent to the Federation for comment.

In many parts of the country maintenance committees had been set up in co-operation with the local Ministry of Transport officials for the help and education of operators. Frequent notices appeared in the R.H.A. and T.R.T.A. journals stressing the importance of avoiding dense exhaust discharge.

He concluded by saying that the Federation were considering setting up a scheme for warning members of the constituent associations of any instances of black smoke being emitted from their vehicles whilst on the road.

S. C. Vince, (Public Transport Association), said that he felt rather like the previous speaker, that at this stage of the proceedings, almost everything that could be said had been said. However, as a representative of the Public Transport Association, he would like to stress one of the points made by Mr. Peter Yorke to the effect that as an association of public service operators including the majority of the largest undertakings in the country, they had no fear of any reasonable enforcement of the law relating to smoking exhausts. It was, without exception, realized, that apart from any unpleasantness arising from excessive smoke, that such a condition was indicative of fuel wastage, and this they are not prepared to accept and, in consequence, took the most active steps to ensure that their engines were running at their maximum efficiency. Furthermore, they were prepared to spend considerable sums of money in routine maintenance work, special equipment, etc., in order to achieve this.

In spite of what had been said by previous speakers, he was convinced that until all concerned with this smoke problem, not only Police, the Ministry of Transport, local authorities, etc., also the operators, themselves, had a universal smoke recording instrument, they could not all speak the same language on the subject. It was felt that the existing instruments were only really suitable for laboratory and development work and whilst they were admirable for these purposes, they needed a high degree of skill in handling and were very expensive. It was essential to have a simpler and cheaper instrument which all could acquire and use, even the smallest operators; for mere visual observations, except in the most extreme cases, were influenced by many variables such as weather conditions, the colour of the background—that is, the road surface, whether it was wet or dry—and not the least, the mental outlook of the observer. It was known that work on developing such an instrument was proceeding, and the sooner it became available the better.

Referring again to the subject of observations, Mr. Vince drew attention to Mr. Lister's Table 1 and said that this was an indication of the difficulties involved—for he maintained that even a person of Mr. Lister's calibre had been grossly misled and that the figures quoted were very far from the true position. He had stated, admittedly, that the figures were approximate, but they were not even that, and to suggest that 25 per cent. of diesel vehicles were bad smokers was completely wrong, that only 18 per cent. of public service vehicles had a clear exhaust whilst lorries had 48 per cent., was entirely contrary to what the position was known to be.

Mr. Vince referred Mr. Lister to a large scale investigation which had been carried out by the Royal Automobile Club and the Automobile Association some three years ago, when approximately 10,000 to 12,000 observations were made in various parts of the country. From this number of vehicles of all types which had been checked, a figure of approximately 8 per cent. was recorded as "bad smokers," *i.e.* the combination of "moderately heavy and heavy" as referred to by Mr. Lister in Table 1. This position, Mr. Vince stressed, was at a time when many diesel users were not so conscious of the desirability of eliminating smoke as they are now.

Mr. Vince then referred to Messrs. Reed and Wallin's paper, and said he was most interested in the investigations they had made into methods for removing the visible products of combustion from exhaust gases. He had long considered that this procedure was the wrong way of tackling this problem and, in common with the authors, felt that the prevention of smoke by proper combustion should be the objective rather than some method of removing it after it had been formed.

Dealing with a proposal of a previous speaker that exhaust pipes should project upwards above the vehicle, Mr. Vince could not agree with him, for it was useless to transfer the nuisance from one spot to another which would, in fact, annoy many people riding on upper decks of other vehicles and also inhabitants of the upper storeys of houses. It was akin to accepting this condition as inevitable and just trying to push it out of sight; he was sure that the formation of smoke must be prevented at the source.

He concluded by reiterating that the public service vehicle operators were most conscious of the fact that visible smoke spelt inefficiency and indicated wasted fuel; this was something that operators could not afford and as an industry take and would continue to take every step that was practicable to prevent smoke formation.

P. Draper, (Shell Mex & B.P. Ltd.), said he was very happy to express his full agreement with the excellent group of papers concerning the exhausts from road vehicles particularly as the true technical position had been presented in such a well authenticated manner and he hoped that the printed papers would effectively silence the violent outbursts which had been such a feature of some of our daily press and semi-technical journals in the past.

He thought that Mr. Lister's excellent survey of the legal and police aspects took the cognisance of the technical aspects so adequately covered by the papers of Mr. Lock and Mr. Waring and he hoped that the practical aspects put forward by Mr.

Lister for ensuring that no black smoke would be encountered in the future would be implemented by suitable legislation.

Mr. Draper felt it not surprising that Messrs. Waring and Lock had covered much the same ground because they had both dealt with technical facts concerning the operation of compression ignition engines and he felt that their complementary papers would have the benefit of mutual support and that they were expressed in a manner which anyone wishing to study the subject could understand.

The Department of Scientific and Industrial Research paper by Messrs. Reed and Wallin considered the problem of pollution on the roads from a different aspect not that of preventing smoke but that of trying to dispose of it before it issued from vehicle exhaust pipes. The problem had proved difficult and in fact not capable of satisfactory solution. Mr. Draper, nevertheless considered this negative result very important as it tended to high-light all the points made in the other papers of the session.

Councillor H. W. Barnes, (Blackpool), said that he agreed mainly with the papers, but he considered it his duty to emphasize strongly that more determined action should be taken by the Government to combat this grave nuisance which is causing much discomfort and danger to the public. Although he had not mentioned the possible injury to health, as a motorist himself he was satisfied that there must be some ill-effects to the individual. At the moment the power to deal with this matter is in the hands of the police authorities, but surely we all realized that detection and prevention of crime was fully taxing their resources. He, therefore, strongly recommended that local authorities and their officers be authorized for the purpose of ensuring that the requirements of the act, were as far as possible enforced. He also felt that any road vehicle, if necessary in the opinion of the authorized officer, be required to undergo tests, and to facilitate the investigations of the emissions, the exhausts of all vehicles using diesel oil should be made to terminate above the height of the vehicle. This would have some effect of reducing the nuisance from the fumes which would be dispersed at a higher level.

Alderman W. L. Dingley, (Warwickshire County Council), said more and more legislation towards a police ridden state was not preferable to the dissemination of experience and knowledge so that every man became his own policeman. For this reason he wished the Conference had been full of science masters. It was very simple to demonstrate even to the juvenile mind the poisonous nature and evils of incomplete combustion.

J. R. Archer-Burton, (Chief Constable for North Riding of Yorkshire), said that a great number of words had been spoken that afternoon, containing a great deal of commonsense and he had been immensely interested in it all. He said there were just one or two points arising from previous speakers that he would just deal with briefly. The first one of course was the matter of enforcement. One speaker had queried as to whether they (the Police) had power to stop in fact. Of course they had power to stop, they did so every day and they would continue to do so in that particular case, as delegates all well knew.

The other point made was the question of photography; there were great difficulties connected with that. It was easy to say, and there was a most interesting report from one of the speakers about what they did in Los Angeles; but up and down the country the police were experimenting with photography for moving vehicles and so forth and there was the aspect that the courts did not readily accept photographs of that nature. For obvious reasons they did not always trust them, but experiments were going ahead.

Another question was the matter of the common informer. As delegates knew it was absolutely contrary to our national character—but informing on what? They welcomed it when the public rang them up and said, " there is a suspicious person loitering near my neighbour's house which I know is vacant," and they liked to know things of that sort. He left it to delegates' own good judgment as to whether they should take the numbers of motor cars that were emitting smoke, but he wished to assure the Chairman and the Conference, that the police would make every endeavour to carry on these duties in spite of their depleted numbers.

A. E. W. Austen, (Chief Engineer, C.A.V. Ltd.), in a written contribution said that nothing in this communication should be taken as dissenting from the view that the reduction of the emission of clouds of black smoke so often seen on our main roads is necessary and urgent.

But there were a number of matters which needed putting into proper perspective.

Injectors. The Conference might have been left with the impression that the most important cause of smoke was the malfunctioning of injectors. In C.A.V.s experience *heavy* black smoke was seldom if ever caused mainly by defective injectors but by overfuelling, often deliberate to try to get more power, incorrect timing due to wear or wrong setting, or partly choked air cleaners.

Faulty injectors could cause " moderately heavy " smoke. Though remarkably reliable and long-lived components they did eventually require attention. The appropriate servicing period varied with the conditions of operation. In special circumstances, *e.g.* with long periods of idling the shortest interval known to C.A.V. was 7,000 miles. In many cases servicing was safely left to 30,000 miles. When they were due for maintenance highly skilled attention was essential. But factory reconditioning was available at trivial cost, *e.g.* in a typical case the cost was less than 1 per cent. of even the fuel cost alone. And it was entirely false economy to neglect injectors since a considerably more expensive loss of fuel consumption nearly always occurred at least as soon as any observable increase of smoke.

Enforcement. It seemed likely that smoke measurement might come, to provide the basis for enforcement. A method for this purpose must be convenient, reliable and the result must be unassailable. It must be said that, although it was reasonably satisfactory in expert hands as a research tool, not all the difficulties with the use of the light absorption, photo-electric type of instrument had been solved. In the United States where work to find a satisfactory standard method had been going on for many years there was a tendency to go away from light absorption methods to a filter paper method.* And such a method might well be accepted on the continent. He said that they might have to consider a filter paper method.

As to acceptable levels, Mr. Austen referred to Mr. Waring having pointed out that the volume of gas emitted as well as the smoke *density* needed to be taken into account. He continued by saying that this could be done quite simply by taking account of the size or maximum horsepower of the engine, and added that in what was understood to be a tentative standard in some continental countries the acceptable limit was varied with rated horsepower, density increased with decrease of horsepower. He referred to a conversion that they had where it had been established that the " just acceptable " value agreed with Mr. Waring's " condemnation limit " for larger engines, but on small engines, however, the " just acceptable " value was much higher. It was Mr. Austen's opinion that some increase of permissible smoke density with decrease of engine size would be not only entirely acceptable but inescapable on practical grounds.

Mr. Austen thought it would be pertinent to ask what would be possible in the future regarding smoke from diesel engines. He spoke of a fundamental study of diesel combustion which a group of his colleagues, in common with some other bodies, were making. They had made a good deal of progress on the earlier parts of the process and had recently started an enquiry into the mechanism of carbon formation, but he did not wish to predict what the future held.

He stated that one clear possibility was already known and that was that with turbo-supercharging if the increase of power demanded was not pushed to the limit but kept to a modest but still economically acceptable value, there would be little doubt that a sufficient excess of air could be provided to give complete absence of smoke.

A. T. Wilford, (London Transport Executive), in a written contribution said that he felt himself in general agreement with the views expressed by the authors of the four papers. With regard to the conclusion reached by Mr. Reed and Mr. Wallin as a result of their investigations at the Warren Spring Laboratory, it had always been his opinion that devices of the kinds described even if available on a commercial basis, would not constitute a real solution to the exhaust smoke problem. Like every other accessory, they would only remain effective if properly maintained. Sooner or later it would be necessary to replace the device by a new or reconditioned unit, the cost of which would have to be added to that of the labour involved in removing and refitting. It seemed a fair conclusion that an operator who already failed to maintain engines and injection equipment to the standard necessary to avoid objectionable exhaust smoke emission, would be equally negligent in maintaining yet another accessory.

The other three papers all made reference to the use of a smokemeter for measurement and control of exhaust smoke emission. London Transport was amongst the concerns who carried out extensive tests with the first six prototype models of the Hartridge-BP smokemeter. It had been found useful in conjunction with engine bench tests. In its modified form it had also been possible to obtain satisfactory results when using it on a vehicle running on the road. For this purpose the meter was temporarily accommodated in the lower saloon, the sampling pipe being brought to the smoke inlet through a convenient open window. Meter readings were taken with the vehicle travelling at a speed of 25 m.p.h., full injection being obtained by judicious application of the brake and where feasible by choosing a stretch of road with a moderate incline. Under such conditions repeatable readings could be obtained to within plus or minus five units. It was unwise, however, to assume that any greater degree of accuracy could be achieved under road test conditions. It was desirable that the vehicle should have been run for a time sufficient to allow the engine to reach its service operating temperature, though it had been found that reasonably repeatable results could be obtained over a wide range of gas entry temperatures.

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* Hunter, H. C. " A Continuous Filtering Type Smokemeter for Automotive Use " (Progress Report of the CFR-DFD Smokemeter Group of C.R.C.), S.A.E. Jnl., Dec. 1953, p. 57.

For day to day and longterm control of exhaust smoke emission, London Transport preferred nevertheless to rely on visual observations by experienced inspectors working to an agreed system of coding which took account of both the volume and density of the emitted smoke. Five such codes were recognized and it might be of interest to mention that the one which was regarded as above the acceptable limit for internal control purposes, corresponded to a Hartridge-BP reading of 55, this figure being five units lower than the "condemnation" limit suggested by Mr. Waring. Inspectors attached to the Research Department's Fuel Economy Control Section, devoted a proportion of their time each week to observation of buses in service and any which was seen to be emitting smoke in excess of the acceptable limit was immediately reported, a visit being subsequently made to the garage concerned to ensure that remedial action had been taken. At three monthly intervals a combined team of inspectors from the Research Department and the Road Services Engineering Department conducted an exhaust smoke survey in which as many as 700 buses were seen and reported upon in the course of a day. Any indication of an increase in the general level of exhaust smoke since the previous survey was made, led to immediate investigation.

Authors' Replies

D. Lister, in his reply, stated that in view of the time he would confine himself to only one or two of the salient points which had emerged in the discussion. He was glad to note the conclusions reached by Messrs. Reed and Wallin in their paper and hoped this would dispose once and for all of the ill-informed agitation for filters to be fitted to diesel exhausts. There were no such filters available. No-one suggested filters to go on top of factory chimneys: the smoke was prevented by proper boiler-house methods, and a similar approach was necessary for diesel smoke. Overloading had been mentioned by some speakers and it was noteworthy that the vehicle manufacturers had thought it necessary recently to ask Parliament for suitable legislation to stop this prevalent abuse by operators. He saw no reason why traffic wardens could not assist in the matter of enforcement. He was not altogether happy about vertical exhausts in view of the existence in this country of double-decked buses, and like Mr. Archer-Burton he did not trust photographs to give reliable evidence of such matters as smoke density.

He was sorry Mr. Vince did not believe the percentages obtained in the survey, and whilst the approximate nature of the figures was acknowledged in the paper, he had taken every precaution to be as accurate as possible, including finding an observation point from which he could see daylight below the vehicles. He was aware that the R.A.C. had done a survey but had never seen their results published and was surprised to learn from Mr. Vince that their unsatisfactory cases were as few as 8 per cent. He begged leave in his turn to doubt their accuracy.

To Alderman Dingley he would say he was unrepentant in his scepticism over education alone, but it was his experience that where education was backed by adequate legal powers, people seemed to become more receptive to it. He regretted he was unable from the figures supplied by the police to answer Mr. Yorke's query about the percentage of public service vehicles prosecuted.

G. Waring, replying, said that it appeared that the general view of many contributors was that the foul exhaust from a diesel engine was a characteristic of that type of prime mover and that so long as there were diesel engines the atmosphere would always be polluted. No mention ever seemed to be made of the diesel engines that run clean on our roads. This point was raised merely to stress that there were clean running diesel engines, and in fact, there was no need at all for a diesel engine to emit a smoky exhaust.

After all, British diesel engines were the finest and cleanest in the world, and if the operating precautions he had mentioned in the paper were carried out regularly, the engines would continue to run without any horrible nuisance from the exhaust.

Unfortunately, on the other hand, a diesel engine would belch a dirty exhaust if neglected or operated in a maladjusted condition. Therefore, technically speaking, any foul exhaust from a diesel engine could be cleaned up to an acceptable standard by the use of proper maintenance and of course, without any adverse disturbance of the makers' recommended fuel pump setting, pump timing or increase in the maximum speed of the engine.

As regards an acceptable standard for smoke, recommendations were being considered by responsible bodies as to what constituted an acceptable standard of exhaust together with means of physically measuring the smoke density emitted from the engine.

Means or devices which tended to nullify the effect of the smoke from the engine in the form of silencers or afterburners were not accepted with any enthusiasm, mainly on the grounds that it was wrong to treat the effect and not the cause of the smoke, and furthermore, that smoke from the engine was a direct indication that the fuel was being uneconomically consumed. This in turn, represented a financial loss to the engine user.

One or two contributors had referred to the improper use of the excess fuel device which was built into the engine as a cold starting aid. A Regulation was being proposed by the Ministry of Transport under the Vehicle Construction and Use Regulation, with the object of preventing the misuse of this device by the driver whilst the vehicle was in motion and the manufacturers of the device also had very cunningly constructed it, so that it was impossible to use it for any other purpose than that for which it was designed.

Meanwhile no effort was being spared to improve the performance of the diesel engine with the object of increasing the power and extending the speed range with a clean exhaust at all times.

The new techniques adopted on the improved engines could also be adapted to older engines in the field, again with the main objects of cleaning up the exhaust together with the general increase of overall performance.

The Des Voeux Memorial Lecture

CLEAN AIR, PUBLIC OPINION AND THE PRESS

By

*Sir Linton Andrews, LL.D.**

YOU have paid me the compliment of asking me to deal with a fascinating but difficult subject. The title suggested was " Clean Air, Public Opinion and the Press." Clean air—that's a controversial theme to begin with. In general we all believe in clean air, just as we all believe in lower taxes and lower rates but higher benefits from the State and from local authorities. We can have clean air at a price, but is it a price that many people are willing to pay? The county in which we are met has an old-fashioned maxim of which you will all have heard, " Where there's muck there's money." So the National Society for Clean Air will have to work hard to convert some of our people. It will only succeed if it convinces them that clean air pays.

Public opinion—that, too, is a knotty subject, an extremely interesting one, but not the kind that you can turn up in an encyclopaedia and grasp in a few minutes' careful reading. What makes public opinion? Who make public opinion? How can it be stirred, how guided, how, if necessary, counteracted? How can we make our own private opinions a public force? How can we get the general public on our side in any proposal for reform of which we are sworn defenders, such as the crusade for clean air?

Such questions breed others. Which institution has the most power to influence public opinion—Parliament, the platform, the Press, the pulpit, radio, television, or the ceaseless arguing that goes on in societies, in clubs, in offices, in our homes, about our difficulties, hardships, our pet reforms, our denunciations of wrong, our hopes for a better world here and of a better world hereafter?

One thing is certain amid all this argumentation day after day, that the topics are very largely suggested by the Press. So the Press very properly is the third panel of my triptych subject—triptych, but not, I hope, cryptic. Here I ought perhaps to speak after all my experience of almost sixty years of journalism with more confidence than on other topics, but I am bound to admit that again and again, trying to solve journalistic problems, I have thought of Anatole France's conclusion, " Upon reflection everything becomes difficult."

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* Editor of *The Yorkshire Post*

The Press is very ready to guide but it is extremely difficult to guide the Press. But I shall do what I can to explain its relation to great causes of reform. That, I am sure, is what you have in mind. The thread of continuity in our title leads us straight from the desirability of clean air to the importance of gaining the support of public opinion if our reform is to take effect; we cannot hope for such an outcome of our efforts until we understand the workings of the Press and make the best use of it we can. Such is the logic of our theme.

To begin with clean air: I take it you are all enthusiasts for this boon and I share your zeal for it. Being a journalist I have had to do most of my work in large cities, mainly London, Paris, Sheffield, Leeds and Dundee, from every one of which, no matter what its attractions, it is a joyous relief to escape to the countryside or a sea cruise.

You have taken in hand a sorely-needed crusade to protect us against the smoke, the dirt, the chemicals, the petrol fumes that beset us in our towns, especially the large industrial ones. Every time I go to London the City and West End streets seem to be almost poisonous with the fumes of the traffic. In my boyhood they smelt like a stable. Now they smell like a garage. I much prefer a horsey smell to a horse-power smell.

You have put forward on many occasions a powerful case for remedial and protective measures against these ills. How are you to get your ideas accepted by a powerful majority of citizens? Why is a crusade, which implies hostile opposition, necessary? If people are so fond of clean air, as everyone on holiday is, why the opposition? Is it a general inability to appreciate what science can do for us? Do we need merely a wider spread of information to ensure enlightenment?

The answers to these questions are to be found in human nature. Most of us are public-spirited to the point of applauding the abolition of smoke or the systematic removal of dirt so long as it will not cause us any expense or inconvenience. We welcome the declaration of a smokeless zone unless we find it means we shall have to spend more on our fuel and our fuel appliances. We hear with interest and approval that corporations are building many flats that are electrically heated, but it would be quite a different matter if we found the Corporation was compelling us to transform our own cheerful firesides, where the coal burns so brightly, into a less picturesque if quite clean and efficient form of heating. We welcome the revolution started by the development of diesel trains, but we raise our eyebrows, and perhaps our voices, at the enormous cost of the British Railways modernization scheme —say £1,660,000,000, money to be spent to make money.

The question becomes much more than the simple one, " Do we want clean air or are we content with grimy and fume-laden towns as they are?" We have to settle problems which are both scientific and economic. The manufacturer and the householder will want to know how we propose to reduce the contamination of the air and above all what it will cost them. You may be sure that compulsory fresh outlays of money will impress them more forcibly than conjectural economies. Hence the need to be as accurate and specific as possible when we are arguing that clean air would bring about great economies. There would be less need for the vast sums that the town populations in particular spend on cleaning materials and the replenishment of soiled curtains, bed covers and all the other soft furnishings. Every housewife knows of those sad and annoying occasions when the chimney has begun to smoke and the smoke brings down soot that settles all over a room.

This Society has been working away at this subject for more than sixty years. It has produced excellent reports, excellent schemes. It has done its utmost to ensure that the private opinion of reformers shall become public opinion. Just how can we carry on this process, how speed it up?

In addressing ourselves to public opinion we must be prepared for its rebuffs. Do not believe it to be something invariably intelligent, highly coherent and compact, quickly responsive to sound argument. Many misconceptions prevail about it and in it.

There is the popular doctrine among many people complaining of their lot that *They* do this and *They* prevent that and *They* impose needless hardships. But who are *They?* Some mysterious governing gang who are supposed to enjoy most of the power in this country and who are all united in the desire to exploit the mass of the people. Some people imagine that this mysterious power is exercised by the politicians. If you say, " But surely you don't think the politicians are all of the same mind," the reply is, " Ah, but this is really a sham fight. They may seem hostile on the platform, but in the tea-rooms and corridors of the House of Commons you find them hob and nob together."

Then again some people think the true governing power over the minds of the country is exercised by the Press and in particular by a few Press lords who are supposed to be able to impose their own ideas on everyone. This, too, is obvious delusion. My old chief, Lord Northcliffe, could not make us all eat standard bread and wear *Daily Mail* hats. The redoubtable Lord Beaverbrook confesses that his Empire Free Trade campaign has failed and is very sad about it. What the public shall think is not within the powers of a few people to determine.

So the first point to realize about public opinion is that it derives from all kinds of tributary sources. We must not suppose it is created only by Government experts, editorial writers, the spokesmen of the professions. Political leaders and editorial writers do not always lead and create public thought. They sometimes march with it, sometimes behind it and sometimes against it. Political leaders are often but voices for those who brief them. Government experts propose remedies for ills that business men or humbler citizens have bemoaned repeatedly till something must be done if only to win votes.

Repeatedly is I think the key word here, or, as Mark Twain would have put it, the boss word. Repetition is the soul of journalism: it is also a motive-power of the democratic process. Think of all the discussions over the garden wall, over pots of tea, over pints of beer, over glasses of port. We can imagine how often housewifes in smoky areas complain of smuts on their sheets, blankets and clothes hanging out on wash day. They are not likely to accept these trials with silent stoicism. Sooner or later their experiences will reach the ears of would-be reformers and make an impression.

We have, indeed, a wonderful network of co-operation by which all kinds of plain folk can tell their troubles to men and women with some influence, such as city councillors, trade union officials, voluntary workers for S.S.A.F.A. and the British Legion. These sympathizers—I hope they are always sympathizers with real hardship—may set official machinery in motion or they may take their reports to higher authority, perhaps to Members of Parliament or local editors.

I cannot imagine that if an M.P. had the chance to remedy someone's distress or if a local newspaper could agitate public opinion by calling attention to some grievance the opportunity would be missed, partly because the Member of Parliament wants to stand well with his constituents and the editor wants to increase the influence and sales of his paper. But I would not say their motive was one entirely of self-interest. Our helpfulness to each other in matters of social reform springs largely from our emotion when conscience tells us something is not fair.

It is often, as we know to our cost, a long process before some grievances reach the stage where authority can give a verdict and decide on reform. What to some people may appear a most desirable improvement may seem to others, especially if their pockets are touched, a faddy nuisance. Some people will complain bitterly of how their domestic peace is disturbed by the shattering din of fly-by-night aeroplanes leaving or arriving at a neighbouring airport, but we may be sure that what to some people are hideous winged monsters appeal to others as signs of immense progress in transport, speed that is of the utmost value in saving time for travellers, and creations of an industry that needs national support.

So you have activity by Residents' and Ratepayers' Associations, Townswomen's Guilds, the National Council of Women, the Noise Abatement Society, and all kinds of national societies and associations. I have heard of a national magazine entitled "Q.P." (meaning "Quiet Please.") There are many other kinds of propaganda whose messages are constantly flowing on to my desk with almost the persistent continuity of news flashes. One society, not I think of long standing, claims that already a million words have been spoken to audiences and on television by its honorary secretary and other National Council members.

I can quote from much nearer home an example of what continued effort is necessary to get a simple reform. Leeds has in the heart of the city a hospital with a magnificent history. It is a centre of wonderful achievement, a centre of first-rate teaching, but being in the centre of the city, within a stone's throw of the Town Hall and the Civic Hall, it is exposed to a great deal of noise, even at night time, when cars and motor cycles go dashing past. Some patients, myself among them, have been repeatedly awakened with nightmare shock when convalescent after an operation. There are endless complaints. Appeals have been made to the local Press, the police, the City Council, to everybody who might be supposed to have some influence in the matter, but the nuisance continues. A lighted notice was put up at night saying "Hospital: Quiet Please," but the nuisance goes on. The road on which the offenders tear past is the Queen's Highway. We are told that motorists and motor cyclists who want to go that way, even though they would lose only a minute or two by taking another route, must be allowed to pass. One cannot close the highway to people who want to use it.

I believe that some day for the sake of the unhappy patients we shall get a better arrangement, but it calls for an immense amount of agitation and propaganda. My paper has printed letters, speeches and leaders about it, till readers are bored—unless they happen to be or have been patients at the hospital. Perhaps it is a pity that this is not a party question. If it were it could be discussed at municipal election meetings and the City Council might be more active about it than it has been.

Some of our methods of opinion-forming and public appeal are not as effective as they used to be. The platform is one of the victims of radio and television. Not so many citizens go to public meetings as they did in the days of Gladstone and Disraeli, Joseph Chamberlain and Asquith. The Churches influence the faithful but seem to have less influence than when more people went to the services and kept Sunday as a holy day. The theatre has occasionally in our time done great service to the cause of reform. We remember Galsworthy's plays that deepened the public love of justice, and Shaw's plays that stung us into thinking about social evils. I may be wrong, but I doubt whether the angry young dramatists of today are doing much to emotionalize and direct our belief in great causes.

But there are two institutions which excercise at least as much power as ever. One is Parliament. This remains our incomparable forum. As a frequent visitor to Gallery and Lobby in the past fifty years and a faithful reader of Hansard I see no decline in the power of Parliament to keep citizens well informed. It is true that we no longer have those breathlessly exciting gladiatorial encounters of men like Gladstone and Disraeli, but we have had heart-stirring oratory from men like Winston

Churchill and Aneurin Bevan and homelier warriors keen to get at the facts and put them before Parliament and the whole country. It is true that Victor Grayson, an M.P. for the Colne Valley, not far from here, horrified Edwardians by declaring Parliament a rotten show, but we may be confident that the House of Commons will continue its useful if controversial work long after he has been forgotten.

We may at times be inclined to disparage the slowness of Parliament, and many of us regret some features of its mechanical party war, even though we realize how its wordy battles awaken and maintain an interest in politics among many people who would be indifferent to, say, the intricacies of economic argument. But there is much about Parliament that commands respect. I should place high among its merits the value of question time. It is an education in our democratic system to listen while Members, fortified with information from their constituents and others, are calling the attention of Ministers to matters that seem to demand attention. A question in the House is very often a means of getting some absurd action or some injustice corrected. It may be that it costs a good deal of money to have Civil Servants digging up the relevant facts for their Ministers but there is not the slightest doubt that a question in the House is a valuable popular safeguard, a point which I am sure has not escaped the notice of your Society. It is not true that only at election times can the constituents assert themselves. By keeping an active M.P. well informed they can keep the good work of informing public opinion going steadily forward.

You will not be wondering what is the other British institution I have in mind as one swaying the people with as much persuasion and force as ever. I mean, as you will have guessed, the newspapers. Here you may expect me to have a neat package of opinions ready, the result of long experience. But just as a training in the higher mathematics may be a training in indecision, just as the man who has visited Rome for a week may have sharper impressions of the Eternal City than a man who has been working there for ten years, so it is possible for someone to know so much about the Press that he hesitates to summarize it in swift simplifications without qualifying clauses that crowd upon his mind.

For example, I should find it hard to estimate with any precision to what extent the Press influences public opinion by its own individual policies. We must make an immediate distinction between the influence exerted by the choice and presentment of news and the influence exerted by editorial comment. In theory, news and opinions should be kept apart. Certainly the news should be given honestly and factually and with no desire to gloss over awkward truths. I always respect a paper if I see one of its foreign correspondents is taking a certain line in some important message and the editor in a leading article is taking a rather different line. It is quite reasonable and proper that the man on the spot in a foreign country should see a problem in a different light from that of his editor steeped in the doctrines of his own Government's policy.

It used to be said of the morning paper, the *Standard*, in Gladstone's time that it read as if the entire paper had come from one hand and one mind, those of the editor, William Mudford. That was regarded as a merit, but I should have thought it a weakness except possibly (though I doubt even this) from a literary point of view. What is the use of sending correspondents all over the world if they are merely going to echo in their cables and special articles opinions formed in Fleet Street?

Nevertheless there is bound to be what is often condemned as selective reporting. In theory a paper prints the important news, all of it. But in practice no paper in the world, not even the gigantic *New York Times*, can print (as it professes to do) all the news that's fit to print. Speeches must be condensed. News must be sifted.

Sub-editing must be selective. And selection means that individual taste must come into play. A newspaper largely reflects the personality of its editor—not indeed just his own private prejudices and pet interests, but what he thinks, using his own distinctive judgement, will appeal to readers. He cannot see every paragraph going into the paper, but he is continually trying to school his leader-writers, reporters and sub-editors in the general principles of news selection, news presentment and the style of writing, argument and description he believes in.

Lord Northcliffe used to say that one of the great powers of the Press was the power of the suppress. And so indeed it is. But happily there is such intense competition among newspapers that very few people are inclined to use the power of the suppress in an unworthy way. They would indeed be soon found out. One dear old gentleman, a former M.P., used to write to me almost every week pointing out that in reports of political speeches the *Yorkshire Post* had left out points which he had seen in the *Manchester Guardian* versions, and he roundly alleged that some nefarious person on my staff, if not myself, was cutting out points that told heavily against Tory arguments. Ultimately I had to silence him by proving how often we printed in the *Yorkshire Post* items and points omitted by the *Manchester Guardian*. Selection was unquestionably necessary and it would have been a miracle if both papers, exercising sub-editorial judgement, had condensed in precisely the same way the enormous mass of news pouring in.

Some people imagine that their letters to the editor are wrongly suppressed, but as controversy is the breath of life to a newspaper a sensible editor welcomes pungent, well-argued letters in opposition to his own policy. Only a small number of letters to the editor can be published every day. Sometimes when a topic has whipped up public interest I have had as many as 300 letters in a morning. It is obviously impossible to print more than a tiny proportion of these. Some excellent letters may not get into print. But the commonest causes of rejection are the libels and inaccuracies in which some readers indulge and the lack of new points made by others.

Readers' letters can be intensely interesting. They sometimes have an authority, a closeness of knowledge and a force of expression which are not to be found among journalists who are writing, perhaps to satiety, day after day, week after week, month after month, year after year. Cartoons may be effective, but I doubt whether they sway opinion as much as they did in the days of F. Carruthers Gould, of the *Westminster Gazette*, and Sir John Tenniel, of *Punch*. They had more of a rarity value in Victorian days.

News, with its immediate impact, often unites the whole nation in emotion An impressive example from journalistic history is that of the revelations from the Crimea by the *Times* war correspondent, Sir William Howard Russell, who opened the eyes of all Britons to the ghastly sufferings of our soldiers, and by his vivid disclosures brought about the fall of the Aberdeen Ministry.

Now we come to the leading articles, still in my judgement the soul of a paper. Some people deride editorials. They say, " After all, it's only one man's opinion." Not so. Even if you have a highly individualistic leader writer like J. L. Garvin, who made the *Observer* famous, or J. A. Spender, whose *Westminster Gazette* leaders were read by all serious politicians, they did not write their articles without incessant efforts to get the latest information from statesmen and to exchange opinions with men of first-class ability. They never wrote in the isolation of a political hermit's cell. The inspiration that Garvin drew from Fisher, the First Sea Lord and the man who modernized the British Navy and had it ready for war in 1914, has been made very plain in a recent book, " The Observer and J. L. Garvin (1908-1914) " by Dr. A. L. Gollin (Oxford University Press).

Very often leaders are decided at an editorial conference. The best thinkers on the staff will contribute, the editor will decide the main line, and the actual leader writer will retire to his typewriter with an abundance of notes. The editor will supervise the resulting article and from his private knowledge will strengthen some surmises, correct deductions he knows to be wrong, and perhaps add more detailed demands than the leader writer attempted and a few epigrammatic touches.

The more serious and weighty the paper the more influential its leaders are. I doubt whether the 200 word leader in snippety basic English, the kind you can get into a couple of inches of fairly large type, can have much influence on the public except by reiteration of the same simple themes time after time. Undoubtedly their readers like to see statesmen given black eyes and bloody noses. The sneer seems to please them more than an argument. Like our party system, this method of attack keeps a great mass of people interested in politics.

There is also warm appreciation of what we call the sunshine Press, with the view that there is no need for heavy taxation, that enterprise should be freed as much as possible and then the profits would roll in and everybody would be happy. Being less given to optimism than some of the more popular papers are I often receive this kind of reproach, " *Must* you give us threepenn'orth of misery every morning?"

It is a good thing that we have all kinds of papers. Democracy provides an arena in which different sides fight it out. Let us by all means toss all the arguments we think important into the midst of the contest and may the best ones win. Perhaps they do. The battle is not always won by the big battalions, or by the party that has the great popular circulations on its side. As long as a party gets ideas under discussion in the democratic arena a strong case has an excellent chance of beating a weak case put forward with the help of a much stronger Press. It is no disparagement of newspapers to say this. It is rather a compliment in implying that newspapers print their opponents' case even though they criticize it and the public is given a chance of making up its own mind.

Having looked at some of the main processes for informing and crystallizing public opinion let us see how we can now use them to further the cause of clean air. Your Society publishes excellent papers on the subject. I was much impressed by one written by Dr. Bronowski on the development of new smokeless fuels. His discussion was lucid and important, especially on the question of premium smokeless fuels. Many housewives would have been cheered by his account of the efforts being made to produce smokeless fuel that is easily handled and stored, reduces the number of times a fire has to be refuelled, ignites easily, burns brightly and long, and picks up well whenever the fire is made. That was the kind of exposition which I think deserves a far wider circulation than in your own journal. It has not had, so far as I saw, the prominence it ought to enjoy in a journalism in which it has to compete for public interest with murder mysteries, film star scandals and tragic accidents to sporting celebrities. Dr. Bronowski did not write only as a scientist for scientists. A good deal of the information he gave could have been popularized for the mass of readers. It could have had a marked influence on public opinion. One must not be too scholarly in manner in trying to persuade the British people of the advantages of clean air. By all means let us have, if possible, statistics showing how respiratory diseases could be reduced by smokeless air. It would be a much more emphatic argument if we could tell all the mothers of this country that if air pollution could be abolished their children could be as berry-brown even in our industrial towns as they are at the seaside.

An appeal to the modern sun-tan worship might be a very effective way of furthering the clean air campaign. Already in towns which have smokeless zones people are noticing how much easier it is to get tanned in the open air. Recently a member of my staff came into the evening editorial conference with a tan as rich as that of somebody just back from the Isle of Capri. He had spent three days watching Yorkshire play cricket at Headingley. Now for 37 years I have been seeing each summer the men who have spent a day or two at a Headingley match: but it is only recently, when the smoke pall over Leeds has become lighter because of certain restrictions on smoke, that I have seen such dramatic tanning achieved in a few hours.

So far as factory smoke is concerned your task should not be a difficult one. For many reasons, labour-saving ones among them, there will be fewer and fewer furnaces stoked to supply the heat and power that industries need. The Englishman with his addiction to the open grate is the man who has to be won over. He has to be converted not only to the idea of clean air—which in general terms he is certain to approve of—but also to the need to play his part in it if he insists on an open fire by using smokeless fuel.

Now if you want to sell anything you have first of all to persuade people that they want it, and then you have to assure them that the price they will have to pay is worth the product they will get. If, as Dr. Bronowski's paper seemed to suggest, they can have a smokeless fuel which has almost all the endearing qualities of coal—easy ignition, bright burning, convenience of storing and handling, reduced problems of ash—it should not be difficult to persuade them that they want it. To offset the disadvantage that they will have to pay more for their glowing smokeless fires than for their blazing, roaring coal fires you will have to hammer home the not so obvious economic gains of smokeless fuel. Extra shillings may have to be spent on smokeless fuel. Very well; show how these can be saved in almost every household by the expenditure saved on the remedies for all the effects of smoke, soot and tarry deposits—the cleaning costs, the repainting costs, the renewal of too-often washed fabrics, the chemists' bills that run up when people are coughing and off their work with smog conditions.

I should like to see incessant emphasis on the value of pure air, emphasis in a form that can be appreciated by all kinds of people, so that the reforms we have in mind become part of the popular thinking. Make the Clean Air Act known to all. Let us enlist the help of M.P.s, of editors of newspapers and magazines, of members of local authorities, of the medical profession, and of scientists generally. You have done extremely good work so far, but we still have to get rid, by every possible means, of the idea that widespread dirt and pollution are an inevitable part of our daily life.

THE ASSESSMENT OF LIABILITY TO SMOG IN TERMS OF WEATHER

By

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Summary

Serious pollution associated with smog conditions occurs with weather of a quiet, anticyclonic type. The incidence of such weather during five consecutive winters has been investigated for 25 towns fairly well distributed over Great Britain. Figures are given which show for each town the total number of days with quiet, anticyclonic weather and also the number of occasions when this type of weather persisted for spells of 2, 3, 4 or more days. It is suggested that this analysis could lead to a more comprehensive investigation aimed at assessing the relative liabilities of various towns to periods of serious pollution.

It is generally agreed that smogs, the unpleasant combination of fog with smoke and other impurities in the atmosphere, represents the worst manifestations of air pollution. The incidence of smog and its severity depend upon a number of factors, for example, the situation of a town in regard to topography, the rate of fuel consumption in the town and neighbouring areas, the ratio of domestic to industrial consumption there, the weather conditions and so on. All these factors are important but it may be a matter of some difficulty to take them all into account in relation to a specific area.

The weather factor itself is a complicated one but, as the author (1959) has pointed out in a study of smogs which were experienced in the winter of 1958-59, an indispensable feature of the more serious smogs is the occurrence of quiet, anticyclonic conditions. Here it should be emphasised that smog is a winter hazard; in summer anticyclones or high pressure systems are to be welcomed because they bring good weather for holidays and outdoor activities generally.

In most problems of applied science in which a number of variables may be involved, it is generally useful to study each variable separately so that its own effects and its frequency of occurrence may be assessed. Quiet, anticyclonic conditions have been identified as an important element in the problem of smog and so it seemed worthwhile to investigate in some detail their frequency of occurrence during the winter months. For this purpose 25 towns were selected in order to provide a good distribution over Great Britain and daily weather charts were examined with the object of determining the number of days when any of the towns were situated in the calm region of an anticyclone. The period covered comprised the five successive winters from November 1954 to February 1959. For this investigation the winter was regarded as extending from November 1st to the end of February. In these four months there is a reasonable chance that a fog or smog may persist all day, whereas in the months March to October it would be most unusual for this to occur.

The results are shown in the following Table which is largely self-explanatory. The first column of figures gives the total number of days in the five winters when each town was subject to quiet, anticyclonic conditions. Dividing the figures in this column by five would give the average for a winter but, as columns 2 and 3 show, the scatter is very great and the average does not provide a reliable guide. The large scatter does, of course, reflect the

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TABLE

Days of Quiet, Anticyclonic Weather in Five Winters (Nov.-Feb.)

				Sequences				
	Total No. of days in 5 *Winters* (1)	*Highest No. of days in any Winter* (2)	*Lowest No. of days in any Winter* (3)	2 *Con-secutive days* (4)	3 *Con-secutive days* (5)	4 *Con-secutive days* (6)	*More than* 4 *Con-secutive days* (7)	*Longest period of Con-secutive days* (8)
Aberdeen . .	39	15	4	5	1	—	1	5
Dundee	41	15	5	4	—	2	1	5
Glasgow . .	46	17	4	2	3	1	1	7
Edinburgh . .	49	17	6	2	1	1	1	7
Newcastle . .	70	32	8	9	6	3	—	4
Durham . .	68	32	7	8	6	3	—	4
Middlesbrough	67	32	7	7	6	3	—	5
Blackburn . .	75	35	7	8	6	4	1	5
Liverpool . .	77	34	7	6	6	4	2	5
Manchester . .	81	37	7	7	6	4	2	5
Leeds	74	36	7	7	6	4	1	5
Sheffield . .	81	37	6	7	6	4	2	5
Stoke on Trent . .	85	38	7	10	6	4	2	6
Hull	74	36	6	6	7	3	2	5
Nottingham . .	84	38	7	10	7	4	1	6
Birmingham . .	90	38	8	10	7	4	2	6
Yarmouth . .	74	35	6	9	4	4	1	5
Swansea . .	73	31	6	10	5	2	2	5
Newport . .	83	36	7	11	7	2	2	6
Cardiff	80	35	7	13	5	2	2	6
Bristol	87	37	7	13	8	3	2	6
Plymouth . .	76	30	8	10	7	2	—	4
London Area . .	87	36	10	8	9	3	1	6
Portsmouth . .	83	35	8	8	7	3	1	6
Chatham . .	79	33	10	10	5	3	—	4

The following are some amplifying notes on the Table:

(*a*) In the case of each town the worst winter (see Column 2) was that of 1958-59 which gave rise to many periods of widespread smog and also prompted a great deal of public reaction. For example, it was estimated that smogs had cost the City of Glasgow about £50,000,000.

(*b*) In contrast to (*a*) above, the best winter showed some variation. In some places the first winter was the best, in others the third or fourth.

(*c*) Fog, and perhaps smog, formed on most but not all of the days covered by Column 1. The exceptional days have not been examined in detail but low relative humidity would account for many of the fog free days. In such circumstances pollution would still be above the average and harmful in various ways such as a reduction of sunshine.

(*d*) As a rule anticyclones are fairly extensive and affect a large area but, even so, this analysis has brought out some of the minor differences between towns not far removed from one another.

(*e*) The sequences in Columns 4-8 give an indication of lengthy periods during which conditions may be favourable for pollution to accumulate and give very high concentrations all over a town. An examination of other factors in the smog problem may show, in some cases at least, the effectiveness of smokeless zones.

wide variations between one year and another in anticyclonic activity. The remaining columns 4-8 give the incidence of sequences of 2, 3, 4 or more consecutive days.

It may be tempting to draw an excessive number of inferences from the Table and, so that this should not be done, it is emphasized that the Table deals with but one factor in a complex problem which, as already mentioned, involves a large number of variables all of them of some importance. As an example, it might be inferred that Birmingham (90 days in five winters) has serious pollution about twice as often as Glasgow (46 days in five winters). But this would ignore the other factors—topographical features, domestic and industrial fuel consumption, smokeless zones, etc.—which would also have to be taken into account before a reliable comparison could be made. However, the Table does help to identify the occasions when one essential factor was present and thus provides a basis for examining the contributions of other factors if the necessary data are available. An extension of the investigation on these lines would give some indication as to whether it would be practicable to assess the relative liabilities of various towns to serious pollution.

Acknowledgement

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THE WORK OF THE CENTRAL ELECTRICITY GENERATING BOARD CONCERNING ATMOSPHERIC POLLUTION CONDITIONS AROUND POWER STATIONS

By

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Summary

The Central Electricity Generating Board has conducted surveys to determine the effect of the emissions from power stations on the general level of pollutions in the vicinity of the stations. The results of the monthly observations published by the D.S.I.R. have been recorded on punched cards for machine sorting. The results show that the national level of dust concentration has fallen considerably since 1950, but the SO_2 concentration has increased since 1952. The effect of power stations on the level of SO_2 pollution was shown to be small, even in relation to rural levels of emission. Short period surveys also showed that no serious concentration occurred in good weather. Other types of survey are also being conducted concerning chimney height and inversion conditions. Improvements to reduce emissions are being developed and introduced, and older power stations are being closed down as new ones are commissioned. Problems arising from oil-firing are also being dealt with.

IT is the business of the Central Electricity Generating Board to provide supplies of electrical energy efficiently and economically. For this purpose power stations are distributed over England and Wales near areas of heavy load demand and where adequate supplies of fuel and water are readily available. Electricity is generated with greater efficiency by large prime movers and a modern power station may consume 4,000 tons of coal per day. The gaseous products of combustion are emitted into the atmosphere and it is the concern of the Board to ensure that the chimney emissions are satisfactorily dispersed in the atmosphere and are not likely to be a source of nuisance. Consequently, in the early stages of planning every known precaution is taken to achieve this aim. These include provisions for optimum combustion conditions in the boiler plant, the installation of flue gas cleaning equipment having a high dust extraction efficiency, and in special cases flue gas washing, and the erection of tall chimneys.

In addition to the precautions taken in the planning stage the Board carry out laboratory research and field investigations to study the effect of power station design and operation on the concentration of atmospheric pollution at ground level in the neighbourhood. The paper discusses briefly some of the work which is being carried out.

A recommendation made in 1932 by a committee set up by the Electricity Commissioners[1] was that in order to avoid the creation of a dust nuisance the minimum height of chimneys should be 2½ times the height of the highest point of the generating station building, an allowance being made where necessary, for other local conditions to compensate for the contour of adjacent land. This was an arbitrary rule and in 1950 the British Electricity Authority instituted long term trials around new power stations to observe the effect of power station design and chimney height on the levels of atmospheric pollution.

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For this purpose the amounts of deposited dust and sulphur dioxide in the air are measured by means of the standard deposit gauge and the lead peroxide instrument at observing stations distributed all round the power stations within a radius of approximately two miles. Observations begin two years before a power station is commissioned in order to obtain sufficient results to characterize the district, and the survey continues until the station has been fully operational for two years. Forty-five surveys of this type have been carried out and an assessment of the results in 1957 showed that power station operation had not caused a significant change in the average levels of dust deposition and SO_2 concentration[2]. More intensive investigations have been carried out at Little Barford to observe the effect of station operation on the dispersion of chimney emissions and to relate the results of direct measurements with those obtained by calculation. The results of the work at Little Barford, which is situated on flat countryside, showed that about 12 per cent. of the dust emitted from the chimneys had fallen within an area having a 2-miles radius from the station, the dust being evenly distributed over the area[3 4].

In order to compare the average level of pollution which occurs round power stations with that of other localities, the results of the monthly observations concerning dust and SO_2 published by the D.S.I.R. Atmospheric Pollution Committee in the monthly Bulletins from 1950 to date, have been recorded on punched cards for machine sorting. This provides a ready means of assessing the concentration levels which characterize rural, urban residential and industrial districts, and trends in the national levels are readily available. For example, it can be shown that the national level of dust concentration had gradually fallen from 13 tons/sq. mile in 1950 to 10 tons/sq. mile in 1959, while the average SO_2 concentration has increased from 1·55 mg SO_3/100 sq. cm/day in 1952 to 2·05 in 1959. The Department of Scientific and Industrial Research have carried out observations around Staythorpe, using the lead peroxide instrument, to study the effect of the power station on the SO_2 concentration in the neighbourhood[5]. By correcting the results for frequency of wind direction to the values obtained down the prevailing wind showed some relationship with the operation of the power station, but the difference between the adjusted high results and the average for the whole survey, namely 1·0 unit, was only of the order of 0·4 units. This low value is typical of rural areas and as shown in the D.S.I.R. Bulletin, some urban areas have total SO_2 figures of 3 to 4 units and known highly industrialized areas from 5 to 11 units.

Long term observations provide information on average conditions, but the individual high and low concentrations, which occur for short periods only, are not detected. For this reason work has begun concerning the short-period measurement of concentrations of SO_2 downwind from power stations in varying meteorological conditions and boiler operation. Observations made round 11 power stations[6] using a portable SO_2 meter specially designed for this purpose at the Central Electricity Research Laboratories[7] showed that there were no serious concentrations of SO_2 in good weather conditions, the maximum concentration being about 30 p.p.h.m. Special studies have been made of plume behaviour, using a balloon technique to observe the path of dust particles[8] and to measure the effective chimney height. The results of studies associated with this work have already been published in the technical press[9,10]. In the London area arrangements are being made to measure the temperature lapse rate occurring in inversion conditions and during periods of fog, the television tower at Crystal Palace being used as an observing station. This work has arisen from the aerial survey made in 1958 in foggy weather[11] which showed the penetration of smog by the hot plumes from power stations.

The work described has been associated mainly with modern power stations designed and installed by the Board. When the Electricity Supply Industry was nationalized in 1948 the British Electricity Authority took over the responsibility of the operation of power plant designed and installed by private companies and municipal authorities when the economic generation of supplies claimed more attention than the possible effects of chimney emissions on atmospheric pollution. Some attention had been given to pollution conditions around power stations, for example at Barton (Manchester) and Bradford[12] but the work was not arranged on a national basis as today. Therefore, included in the number of power stations operated by the Board are those designed and installed since 1950 using efficient methods of flue gas treatment and high chimneys, those designed immediately after the war, incorporating the best possible equipment available at that time, and those commissioned before the war. Modifications are being made where necessary, to the stations commissioned shortly after the war by improvements to the flue gas cleaning equipment or by the erection of high chimneys as at Blackburn Meadows, Kirkstall, Thornhill and Spondon. The older stations are gradually being closed down as new plant is commissioned to take the load, and as National Grid requirements permit.

Since 1955 a number of power stations have been converted to oil-firing which has brought new problems concerning the character of chimney emissions. Arising from intensive studies of the flue gas characteristics, remedial measures have been successfully applied such as improved combustion control and the use of flue gas additives. Both long and short term observations are being made to measure the effect of these measures. It may be said that the Board is as advanced in these studies as any other country in the world.

In all matters relating to atmospheric pollution there is a close collaboration with D.S.I.R. Warren Spring Laboratory and the scientific information resulting from the Board's researches is regularly communicated.

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SAMPLING FOR 3:4 BENZPYRENE FROM CONTINUOUS COMBUSTION APPLIANCES FIRED BY PETROLEUM FUELS

By

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Summary

1. In recent years attention has been drawn to the possibility of 3:4 benzpyrene, a trace decomposition product resulting from incomplete combustion which may be present in smoke, being a cause of cancer in humans and animals. As part of a programme to investigate the composition of flue gases from continuous combustion plant, fired by petroleum fuels, measurements have been made for 3:4 benzpyrene. Appliances ranging in size from a simple cooking ring, using liquified petroleum gas, to a water tube boiler, using heavy fuel oil, have been tested.

2. It is shown that in all cases the 3:4 benzpyrene content of sampled solids and " oil " was less than the limit of detection by the analytical method employed, i.e. less than one microgramme. This means that the quantity of 3:4 benzpyrene emitted from continuous combustion plant, fired by petroleum fuel, is likely to be less than 0.006 parts per million of fuel burnt.

Introduction

IN recent years evidence has accumulated to suggest that some forms of cancer in humans and animals are associated with soot and dirt. This suggests the possibility that man-made contaminants of our atmosphere possess carcinogenic properties. A review of fifty years' clinical experience indicated that a large percentage of those cases of cancer which could be attributed to soot were in fact probably due to benzpyrene, a trace polynuclear aromatic hydrocarbon[1].

The sources of air borne soot and solids are considerable, and include domestic appliances, boilers, industrial furnaces and process plant. In view of the increasing use of petroleum fuels for continuous combustion equipment a research programme has been initiated to investigate the extent to which they contribute to air pollution and so allow comparison with major sources of contamination. As part of this programme attempts have been made to measure the 3:4 benzpyrene content in the exhausts of appliances ranging in size from a cooking ring to a water tube boiler.

The significance of the results obtained in that part of the programme concerned with 3:4 benzpyrene are discussed in this paper.

Fuels and Appliances

The fuels used in the appliances tested ranged from liquified petroleum gas to heavy fuel oil. Data on the fuels are given in Table 1.

Details of the appliances tested, together with operating conditions, are given in Table 2.

Test Equipment and Analysis

1. *Sampling Equipment*

The exhaust gases produced by each appliance were continuously sampled at approximately 1 cu. ft./min. through a probe and collecting train by means of a vacuum pump as shown in Figure 1.

Referring to Figure 1 it will be seen that the gases were sampled isokinetically and that the probe was heated to prevent condensation of gaseous constituents. On leaving the probe the sampled products passed first through a set of cyclones to remove coarse particulate matter and then through an

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TABLE 2

DETAILS OF APPLIANCES TESTED AND SAMPLING CONDITIONS

Appliance	Type of Burner	Capacity of Unit		Fuel Used	Test No.	Operating Condition	Exhaust Conditions at Sampling Point			Gas Sampled	
		Btu^s/hr	lb steam /hr				CO_2 (% vol dry basis)	Equivalence Ratio (1)	Smoke No. (2)	Vol at NTP (cubic metres)	Equiv. Fuel Burnt to Produce Sample (grams)
Cooking ring	Gas	12,000	-	Liquified Petroleum Gas	1	No Cooking pot	6.8	2.05	< 1	12.95	542 (8.2 cu ft)
					2	Continuously cooled Cooking pot	12.5	1.11	< 1	11.00	850 (12.9 cu ft)
Free standing convection space heater	Long drum wick type	12,500	-	1st Grade Kerosine	3	Normal Max capacity	5.8	2.56	< 1	8.90	314
Free standing radiation space heater	Short drum vaporising type	9,000	-	1st Grade Kerosine	4	Normal Max capacity	6.3	2.37	< 1	11.80	466
Flued space heater	Pot	30,000	-	2nd Grade Kerosine	5	Normal Max capacity	7.8	1.91	2	15.40	714
					6	Bad Producing smoke	9.9	1.51	6-7	6.50	381
Domestic boiler	Pot	25,000	-	2nd Grade Kerosine	7	Normal Max capacity	3.2(3)	4.65	3	9.72	185
					8	Bad Producing smoke	4.6(3)	3.24	8	8.87	242
Sectional water boiler	Pressure Jet atomiser	250,000	-	Domestic Burning Oil	9	Continuous Max capacity	5.8	2.61	1	10.45	367
					10	Cycling 5 min max capacity 5 min shut down	During firing periods 7.6	During firing periods 2.00 overall 4.00	At light up 7 Steady running 1	16.8	394
Economic type steam raising boiler	Steam atomiser	-	6,000	Fuel Oil 950 sec	11	Normal 80% full load	8.2	1.92	2-3	13.42	653
Water tube steam raising boiler	Pressure Jet atomiser	-	6,000	Fuel Oil 3,000 sec	12	Normal Full load	10.5	1.50	3-4	12.40	782

(1) Equivalence ratio = $\frac{\text{measured air/fuel ratio}}{\text{Stoichiometric air/fuel ratio}}$

(2) Stain obtained by drawing gases through No.4 Whatman filter paper (2,250 cu in./sq in. filter area)
Stain compared with standard shade card (10 shades varying from 0 = White to 9 = Black)

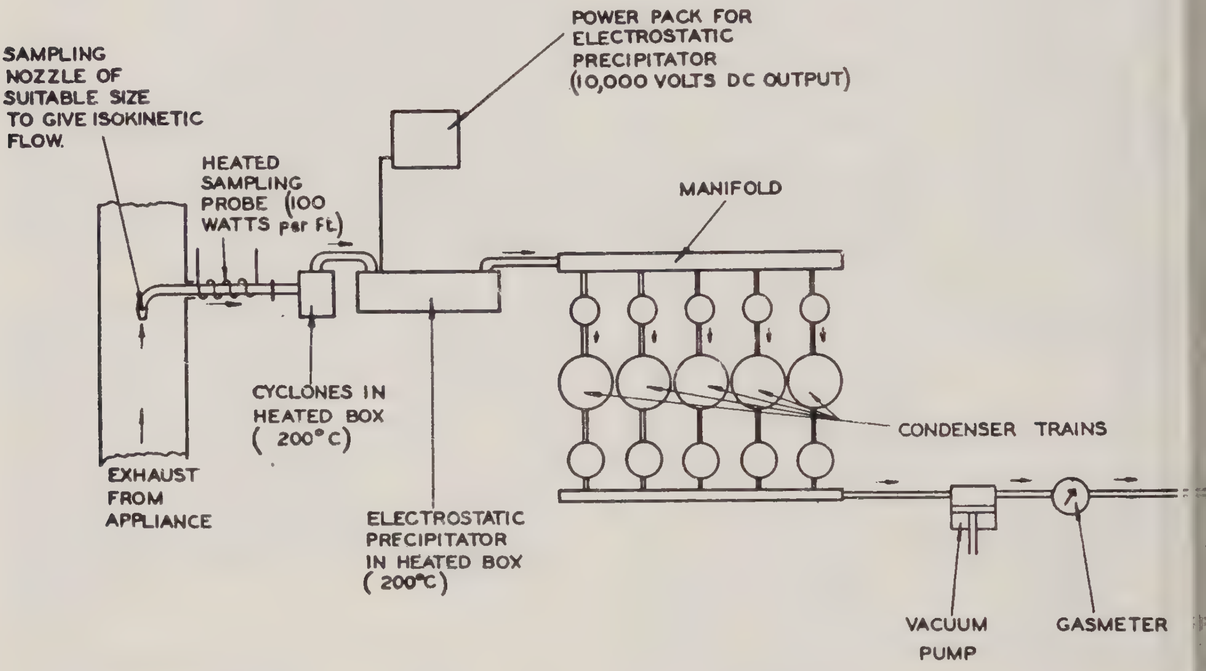
(3) Low CO_2 content because of dilution air admitted by draught controller

TABLE 1

DETAILS OF FUELS

Fuel		Liquified Petroleum Gas (1)	1st Grade Kerosine (2)	2nd Grade Kerosine (3)	Domestic Burning Oil (4)	Fuel Oil (950 second) (5)	Fuel Oil (3,000 second) (6)
Density (gaseous state at NTP)	lb/cu ft	0.1457	-	-	-	-	-
Specific gravity	60°F/60°F	-	0.7812	0.7862	0.8370	-	-
Specific gravity	140°F/60°F	-	-	-	-	0.9240	0.9360
Viscosity at 70°F	cS	-	1.85	-	-	-	-
Viscosity at 100°F	cS	-	1.42	1.4	2.97	225.60	613.4
Carbon content	% wt	82.37	85.5	85.58	84.68	84.27	84.49
Hydrogen content	% wt	17.63	14.5	14.42	15.30	11.29	11.14
Ash content	% wt	-	-	-	-	0.05	0.04
Calorific value (net)	Btu^s/cu ft	2,881	-	-	-	-	-
Calorific value (net)	Btu^s/lb	-	18,750	18,560	18,400	17,640	17,210

(1) (2) (3) (4) - Distillate Fuels (5) (6) - Fuel Oils


POWER PACK FOR ELECTROSTATIC PRECIPITATOR (10,000 VOLTS DC OUTPUT)
SAMPLING NOZZLE OF SUITABLE SIZE TO GIVE ISOKINETIC FLOW.
HEATED SAMPLING PROBE (100 WATTS per Ft)
MANIFOLD
CYCLONES IN HEATED BOX (200°C)
CONDENSER TRAINS
EXHAUST FROM APPLIANCE
ELECTROSTATIC PRECIPITATOR IN HEATED BOX (200°C)
VACUUM PUMP
GASMETER

electrostatic precipitator to remove fine particulate matter. Both the cyclones and precipitator were housed in heated boxes to prevent condensation of gaseous constituents. Details of the cyclones and precipitator are shown in Figure 2.

After removal of the solids each sample was passed through a bank of five condensate trains arranged in parallel. These progressively cooled the gases to remove condensable material at temperatures of 0°C., −25°C. and −65°C. Details of a single condensate train are shown in Figure 3.

Metering of the sample was by means of a gasmeter at the vacuum pump outlet.

2. *Routine Measurements*

Operating conditions for each appliance were continuously checked by measuring the CO_2 content in the exhaust gases by means of a conventional Orsat apparatus. Routine smoke measurements were also conducted using a filter type smokemeter.

3. *Analysis of Collected Solids and Condensed Oil*

For each test the solids in the

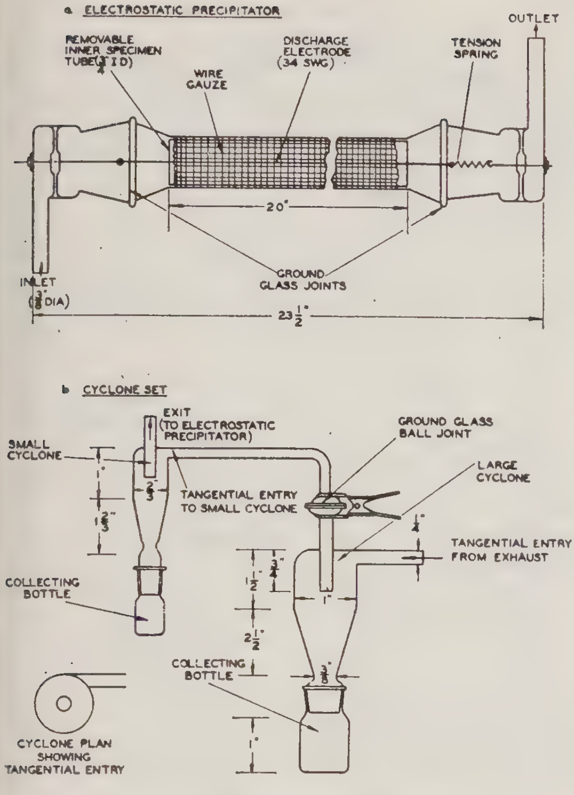


FIG 2 SOLID SAMPLING APPARATUS

cyclones and precipitator were bulked, likewise the fractions from the various condensers were extracted with methylene chloride to obtain one bulked " oil " sample.

Analysis for 3:4 benzpyrene was conducted independently on each solid sample and on each " oil " sample. The method used is suitable for the determination of polynuclear aromatic hydrocarbons in soot, solid hydrocarbons or oil. Briefly the procedure is as follows:

The sample is dissolved in cyclohexane and passed down a column of slightly deactivated alumina[2]. The fractions eluted by cyclohexane are examined in an ultra-violet spectrometer. Individual polynuclear hydrocarbons, including 3:4 benzpyrene, can be estimated and identified by their U.V. spectrum in cyclohexane solutions.

Test Programme

1. *Size of Sample*

Consideration was given to the size of sample necessary to give a confident limit of sensitivity. Pybus[1] gives data for 3:4 benzpyrene concentration in coal smoke which can be expressed as 4·2 parts per million by weight of coal burnt. The limiting sensitivity level for fuel oils in the test programme was taken as 100 times lower than the coal smoke discharge. For distillate fuels the limiting sensitivity level was taken as 400 times lower than coal smoke discharge. These levels are equivalent to 0·04 and 0·01 parts per million on fuel for fuel oil and distillate fuel respectively.

The limiting quantity of 3:4 benzpyrene that can be detected by the analytical method employed is one microgramme. Thus to obtain the minimum sensitivity level accepted for this work, the exhaust gas samples required were those produced by combustion of at least 25 grams and 100 grams of fuel for fuel oil and distillates respectively.

Reference to Table 2 shows that the equivalent fuel quantities burnt to obtain samples in the test programme varied from 185 to 850 grams. These quantities are well above the minimum required to obtain the desired sensitivity.

2. *Test Conditions*

Eight appliances were tested, the smallest being a simple cooking ring and the largest a 6,000 pound per hour steam capacity water tube boiler. Where possible two operating conditions were covered on each appliance; (*a*) normal continuous operation and (*b*) operation calculated to produce solids and unburnts. Normal continuous operation was considered satisfactory when a smoke number of less than 3 was obtained. A smoke number of more than 5 was considered representative of excessive solid production.

With the cooking pot and sectional water boiler variants of the (*b*) condition were investigated. The cooking ring was operated with a continuously water cooled vessel, calculated to give flame chilling. The sectional water boiler was operated under cycling conditions, five minutes firing, five minutes off. It was known that on this plant the rate of solid emission, in the first few seconds after light up, was

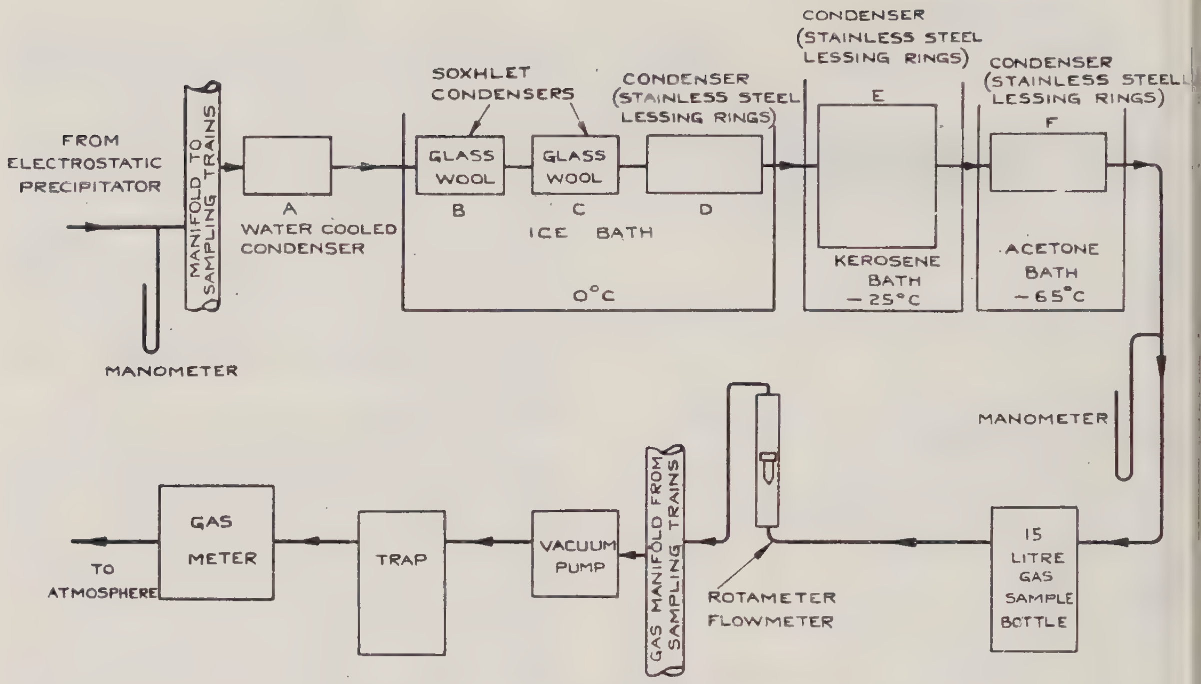

FROM ELECTROSTATIC PRECIPITATOR
MANOMETER
MANIFOLD TO SAMPLING TRAINS
A
WATER COOLED CONDENSER
SOXHLET CONDENSERS
GLASS WOOL
B
GLASS WOOL
C
CONDENSER (STAINLESS STEEL LESSING RINGS)
D
ICE BATH
0°C
CONDENSER (STAINLESS STEEL LESSING RINGS)
E
KEROSENE BATH
− 25°C
CONDENSER (STAINLESS STEEL LESSING RINGS)
F
ACETONE BATH
− 65°C
MANOMETER
15 LITRE GAS SAMPLE BOTTLE
ROTAMETER FLOWMETER
GAS MANIFOLD FROM SAMPLING TRAINS
VACUUM PUMP
TRAP
GAS METER
TO ATMOSPHERE

FIG.3. ARRANGEMENT OF A SINGLE CONDENSER TRAIN FOR "OIL" COLLECTION

TABLE 3

TOTAL SOLIDS EMITTED AND 3:4 BENZPYRENE CONTENT

Test No.	Solids			3:4 Benzpyrene in Solids		
	Collected mg	% of Fuel Burnt	Concentration in Gas Sample mg/100m^3	Analytical Result (1) µg	ppm on Fuel Burnt	Concentration in Gas Sample µg/100m^3
1	Not Detected			-	-	-
2	Not Detected			-	-	-
3	Not Detected			-	-	-
4	Not Detected			-	-	-
5	7.7	0.001	50	< 1	< 0.0014	< 6.5
6	30.6	0.008	470	< 1	< 0.0026	< 15.4
7	31.3	0.017	322	< 1	< 0.0054	< 10.3
8	119.0	0.048	1,340	< 1	< 0.0041	< 11.3
9	4.1	0.001	39	< 1	< 0.0027	< 9.6
10	6.4	0.002	76(2)	< 1	< 0.0025	< 11.9(2)
11	360.0	0.055	2,680	< 1	< 0.0015	< 7.4
12	1230.0	0.157	9,920	< 1	< 0.0013	< 8.1

(1) Limit of Detection 1 µg (2) During Firing Period

TABLE 4

TOTAL CONDENSABLE "OIL" EMITTED AND 3:4 BENZPYRENE CONTENT

Test No.	Condensable "Oil"			3:4 Benzpyrene in Condensable "Oil"		
	Collected mg	% of Fuel Burnt	Concentration in Gas Sample mg/100m^3	Analytical Result (1) µg	ppm on Fuel Burnt	Concentration in Gas Sample µg/100m^3
1	142.8	0.026	1,100	< 1	< 0.0018	< 7.7
2	256.0	0.031	2,330	< 1	< 0.0012	< 9.1
3	86.3	0.028	970	< 1	< 0.0032	< 11.2
4	175.8	0.038	1,490	< 1	< 0.0021	< 8.5
5	580.0	0.081	3,770	< 1	< 0.0014	< 6.5
6	900.0	0.236	13,800	< 1	< 0.0026	< 15.4
7	226.0	0.094	2,320	< 1	< 0.0054	< 10.3
8	1217.0	0.658	13,700	< 1	< 0.0041	< 11.3
9	201.0	0.051	1,920	< 1	< 0.0027	< 9.6
10	833.0	0.227	9,920 (2)	< 1	< 0.0025	< 11.9 (2)
11	1200.0	0.184	8,930	< 1	< 0.0015	< 7.4
12	270.0	0.035	2,180	< 1	< 0.0013	< 8.1

(1) Limit of Detection 1 µg (2) During Firing Period

higher than during continuous operation. (Variants with both the cooking pot and the section water boiler were possibly more typical of practical usage than normal continuous operation).

It was not possible to operate the free standing heating appliances or the steam raising plant under (*b*) conditions. The former do not lend themselves to continuous faulty operation. The latter were being used to supply steam for important industrial processes and alteration from normal operation was not permitted.

Details of each test and the exhaust gas conditions at the sampling point for each appliance have been included in Table 2.

The quantity of solids collected during each test and the results of analyses for 3:4 benzpyrene are shown in Table 3. Similar data for the " oil " samples are shown in Table 4.

Discussion

1. 3:4 *Benzpyrene*

The results of analyses for 3:4 benzpyrene, Tables 3 and 4, show that in no test was this substance detected, i.e. if 3:4 benzpyrene was present in the solid and " oil " samples collected, quantities were less than the limit of detection of one microgramme.

At the *minimum* sensitivity level for the programme the weight of benzpyrene emitted, by the appliance tested, was less than 0·04 and 0·01 parts per million of fuel burnt for operation on fuel oils and distillate fuels respectively. In fact, because the samples were obtained from combustion of fuel quantities many times larger than specified, see Table 2, the sensitivity level achieved was considerably higher than the accepted minimum. Thus, further reference to Tables 3 and 4 shows that it can be confidently stated that the quantity of 3:4 benzpyrene emitted was in all cases actually *less than* 0·006 *parts per million on fuel burnt, irrespective of fuel type and operating conditions.*

It is perhaps of interest to see what the above figure means in terms of concentration in the *actual flue gases.* Figures are included in Tables 3 and 4 expressed as microgrammes per standard volume of flue gas sampled. It will be seen that for every test the analysis gave a result of *less than* 16 microgrammes per 100 cubic metres of flue gas. Although results have not been given it is pertinent to mention that the samples, including those obtained under deliberately promoted smoke producing conditions, were analyzed for total quantities of polynuclear aromatic hydrocarbons. In no case were these compounds detected. Since 3:4 benzpyrene is one of a number of polynuclear aromatic hydrocarbons it seems very probable that, under normal operating conditions, the concentrations in the flue gases of this material alone were *very much less* than the figure of 16 microgrammes per 100 cubic metres. It would appear, therefore, that the 3:4 benzpyrene content of flue gases from continuous combustion plant, operating on petroleum fuels, should not normally exceed concentrations found in the open atmosphere in urban areas, i.e. 1·3 to 6·8 microgrammes per 100 cubic metres[1,3,4].

Bearing in mind that the samples referred to in this paper were taken from actual flue gases, and that if they had reached ground level a high degree of dilution would have taken place, the results obtained from the test programme strongly suggest that continuous combustion plant, operating on petroleum fuels, do not normally seriously contaminate our breathable atmosphere with 3:4 benzpyrene.

2. *Contamination by Solids and Unburnt Material*

Since cancer is associated with dirt and grime it is of interest to examine the contribution to atmospheric pollution made by continuous combustion appliances using petroleum fuels.

Referring to Table 3 it can be seen that expressed as a percentage of the fuel burnt the solids produced by the appliances tested, under normal operating conditions, were less than 0·017 per cent. for distillate fuels and less than 0.157 per cent. for heavy fuels. Similarly from Table 4 it will be seen that the unburnt "oil" produced did not exceed 0·094 per cent. for distillate fuels or 0·184 per cent. for fuel oils. It seems likely, therefore, that under reasonable operating conditions, the total solids and unburnt materials emitted by oil fired continuous combustion plant will not exceed 0·35 per cent. of the fuel burnt. With distillate fuels the level should be considerably lower.

Conclusions

1. In tests on appliances using petroleum fuels and ranging in size from a simple cooking ring, using liquified petroleum gas, to a water tube boiler, using heavy fuel oil, the 3:4 benzpyrene content in the exhaust gases was in all cases less than the limit of detection by the analytical method employed (i.e. one microgramme).
2. The quantity of 3:4 benzpyrene emitted from continuous combustion appliances, operating on petroleum fuels, is likely to be *less than* 0·006 parts per million of fuel burnt.
3. Total solids and unburnt materials emitted from continuous combustion appliances, operating on petroleum fuels, is not likely to exceed 0·35 per cent. of the fuel burnt when reasonable operating conditions are maintained.

Acknowledgements

1. For undertaking the analytical work on samples and assisting in sampling from the flues of the appliances tested the author is indebted to Mr. C. A. Miller and Mr. A. R. Javes of Analytical Section, Petroleum Division, BP Research Centre, Sunbury-on-Thames, Middlesex.
2. The author thanks The Chairman and Directors of The British Petroleum Company Limited for permission to publish this paper.

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TRENDS IN THE POLLUTION OF THE AIR OF GREAT BRITAIN BY SMOKE AND SULPHUR DIOXIDE, 1952-1960

By

(Miss) J. D. Carroll, S. R. Craxford, H. E. Newall
*(Mrs.) M.-L. P. M. Weatherley**

Summary

An attempt is made in this paper to estimate changes in the emission of smoke and sulphur dioxide into the air of this country during the period 1952-59, and to see to what extent they are reflected in changes in the concentration of these pollutants near ground level, at least, as far as such changes can be estimated from the data obtained by the D.S.I.R. Cooperative Investigation of Atmospheric Pollution. One of the factors concerned in bringing about such changes is the Clean Air Act, which came into force in 1956 and which has curbed the emission of smoke but has no direct effect on pollution by sulphur dioxide.

Emission of Smoke and Sulphur Dioxide

THE consumption of fuels in each year in the period 1952 to 1959, and the emissions of smoke and sulphur dioxide into the atmosphere by the main users of fuels are given in Tables 1 and 2 and are shown graphically in Figures 1, 2 and 3.

From the results in the tables it is seen that the emission of smoke increased, if anything, from 1952 to 1954, but a steady decrease then set in, and the amount in 1959 was 20 per cent. less than in 1952. On the other hand, the amount of sulphur dioxide emitted increased steadily from 1952 to 1958 and decreased slightly in 1959. The amount emitted in 1959 was about 11 per cent. more than in 1952.

The decrease in smoke was largely a decrease in industrial smoke, although domestic smoke also decreased since 1954, particularly in 1957 and 1959. This was probably due partly to changing habits in domestic heating and partly to abnormally warm weather throughout 1959.

The largest contribution to the increased emission of sulphur dioxide was that made by the increased generation of electricity. The increase in the average sulphur content of the coal and the increasing use of fuel oil also contributed.

TABLE 1

Consumption of Fuels in Great Britain from 1952 to 1959
Million tons

	1952	1953	1954	1955	1956	1957	1958	1959
Coal								
Domestic	36·8	37·1	38·2	37·1	37·5	35·5	36·0	34·1
Electricity works ..	35·5	36·7	39·6	42·9	45·6	46·5	46·2	46·0
Railways	13·9	13·4	13·0	12·2	12·1	11·4	10·3	10·2
Industrial. etc. ..	63·9	63·9	65·5	64·5	62·5	59·2	54·4	51·7
Coke ovens	25·1	25·9	26·6	27·0	29·3	30·7	27·8	25·7
Gas works	27·7	27·1	27·3	27·9	27·8	26·4	24·8	22·5
Coke (excluding gas works and blast furnaces)	14·7	14·7	15·5	16·0	15·1	13·6	13·4	12·5
Oil								
Diesel and gas oil ..	1·2	3·0	3·3	3·8	4·2	4·1	5·0	5·3
Fuel oil								
Electricity works ..	small	< 0·1	0·2	0·2	0·4	0·6	2·6	4·1
Other users ..	3·5	3·8	4·2	5·2	6·1	6·3	8·0	9·7

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* Warren Spring Laboratory, D.S.I.R.

Table 2

Emissions of Smoke and Sulphur Dioxide by the Main Users of Fuels; 1952-1959

Thousand tons

	1952		1953		1954		1955		1956		1957		1958		1959	
	Smoke	Sulphur dioxide	Smoke	Sulphur dioxide	Smoke	Sulphur dioxide	Smoke	Sulphur dioxide	Smoke	Sulphur dioxide	Smoke	Sulphur dioxide	Smoke	Sulphur dioxide	Smoke	Sulphur dioxide
Coal																
Domestic	1290	88	1300	890	1340	910	1300	890	1310	900	1240	910	1260	920	1190	860
Electricity works	small	960	small	970	small	1050	small	1140	small	1210	small	1300	small	1310	small	1310
Railways	280	380	270	360	260	350	240	330	240	330	230	330	210	300	200	290
Industrial, etc.	770	1730	770	1730	790	1770	770	1740	750	1690	650	1710	540	1570	520	1490
Coke ovens	small	100	small	100	small	100	small	100	small	100	small	100	small	100	small	100
Gas works	small	200	small	200	small	200	small	200	small	200	small	200	small	200	small	160
Coke (excluding gas works and blast furnaces)	nil	400	nil	400	nil	420	nil	430	nil	410	nil	390	nil	390	nil	360
Oil																
Diesel and gas oil	small	10	small	30	small	30	small	40	small	40	small	40	small	50	small	50
Fuel oil																
Electricity works	small	small	small	small	small	small	small	small	small	20	small	40	small	160	small	250
Other users	small	210	small	230	small	250	small	310	small	370	small	380	small	480	small	580
Total	2340	4870	2340	4910	2390	5080	2310	5180	2300	5270	2120	5400	2010	5480	1910	5450
Smoke/Sulphur dioxide	0.48		0.48		0.47		0.45		0.44		0.39		0.37		0.34	

TABLE 3

Trends in Concentrations of Smoke throughout the Country

Period	*Number of gauges*	*Percentage of total showing*		
		Increase	*No change*	*Decrease*
1952-60	47	30	35	35
1955-60	106	15	25	60

Concentrations of Smoke near Ground Level throughout the Country

Of all the sites at which smoke concentrations were determined in the year 1959-60 (observations are always averaged for the year ended 31st March to avoid splitting the winter period) the number at which measurements extended back to cover the year

1958-59 was only 266
1957-58 was only 189
1956-57 was only 138
1955-56 was only 106
1954-55 was only 64
1953-54 was only 49
1952-53 was only 47

The data obtained at these sites were examined for trends in two ways.

Firstly, the run of average yearly smoke concentrations at each of the 47 sites where observations were made over the period 1952-60 was examined to see at how many of them the concentration had increased, decreased or showed no very decided trend. Similar counts were made for the 106 sites covering the period 1955-60. The results are given in Table 3.

The number of sites at which pollution by smoke has decreased is greater than the number at which it has increased.

The second examination for trends was made by averaging the smoke concentrations for the 47, 49, 64, 106, 138, 189 and 266 sets of sites for each of the years concerned, as shown in Table 4.

Examination of Table 4 suggests that there was a decrease in smoke in the period up to 1954-5, followed by an increase in 1955-6, a decrease to 1957-8, a slight increase in 1958-9, and a very large decrease in 1959-60.

A statistical examination of the significance of these trends using Student's " t " test showed that the fall in the average ground-level concentration between 1952-3 and 1954-5, the rise in the following year and the subsequent fall from 1955-6 to 1957-8 were probably significant, but the

TABLE 4

Average Smoke Concentrations throughout the Country

Year	*Number of gauges*	*Smoke microgrammes/ cubic metre*
1952-3	47	204
1953-4	47	191
1954-5	47	183
1955-6	47	206
1956-7	47	198
1957-8	47	197
1958-9	47	199
1959-60	47	155
1953-4	49	189
1954-5	49	187
1955-6	49	206
1956-7	49	198
1957-8	49	196
1958-9	49	203
1959-60	49	159
1954-5	64	190
1955-6	64	208
1956-7	64	196
1957-8	64	190
1958-9	64	202
1959-60	64	159
1955-6	106	233
1956-7	106	211
1957-8	106	198
1958-9	106	208
1959-60	106	166
1956-7	138	211
1957-8	138	193
1958-9	138	202
1959-60	138	158
1957-8	189	202
1958-9	189	207
1959-60	189	162
1958-9	266	209
1959-60	266	165

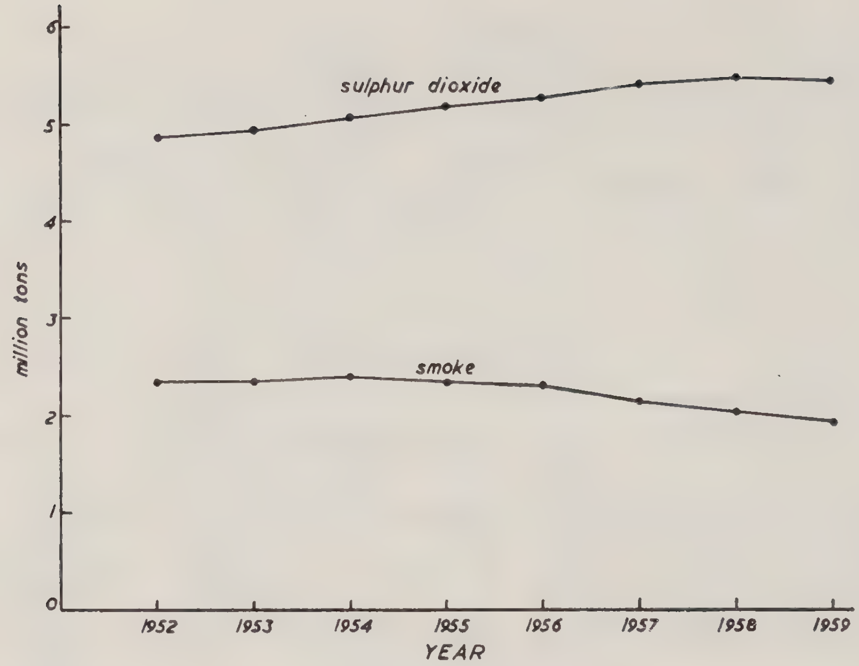

Fig. 1 Trends in emission of smoke and sulphur dioxide in Great Britain, 1952-1959

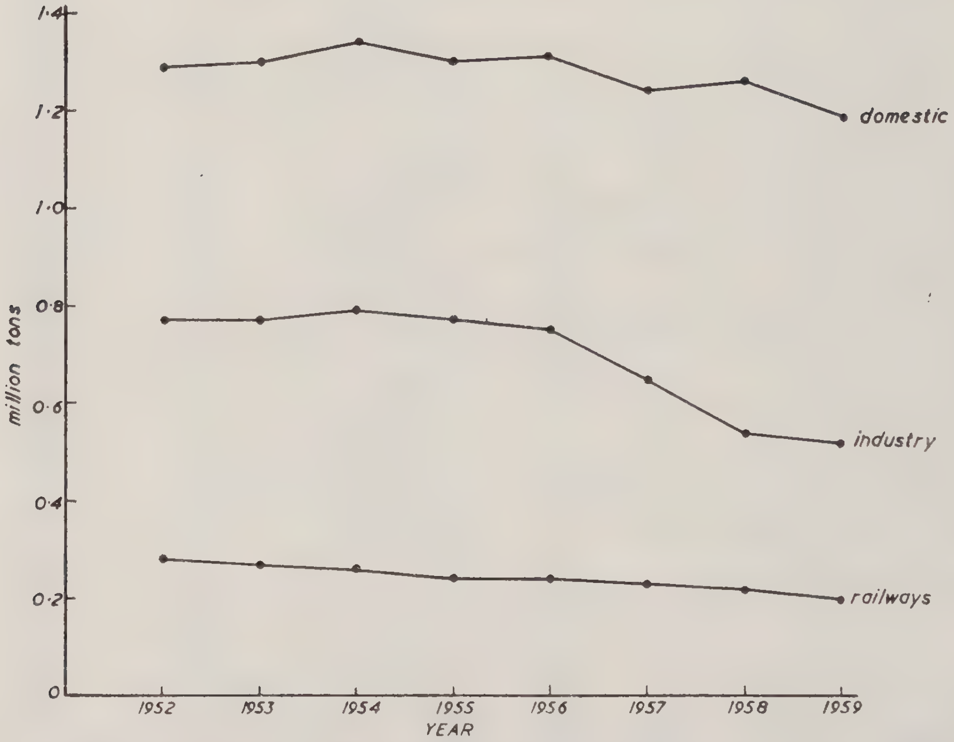

Fig. 2 Trends in emission of smoke by groups of consumers in Great Britain, 1952-1959

rise in 1958-9 was not significant. The decrease in 1959-60 was, naturally, highly significant.

Comparison with the corresponding data for sulphur dioxide (see the following two sections) indicates that the peaks in 1955-6 and 1958-9, and the dip in 1959-60 were brought about by changes in weather conditions which determine the tendency of pollutants to build up near ground level, or to be dispersed harmlessly int the upper air, and which also determin how much fuel is burnt for heating purposes in any given winter. Taking thi into account there is left a marke underlying downward trend in smok concentrations, corresponding roughly wit the downward trend in emission.

The trends discussed in this section ar obtained from averages from all the smok

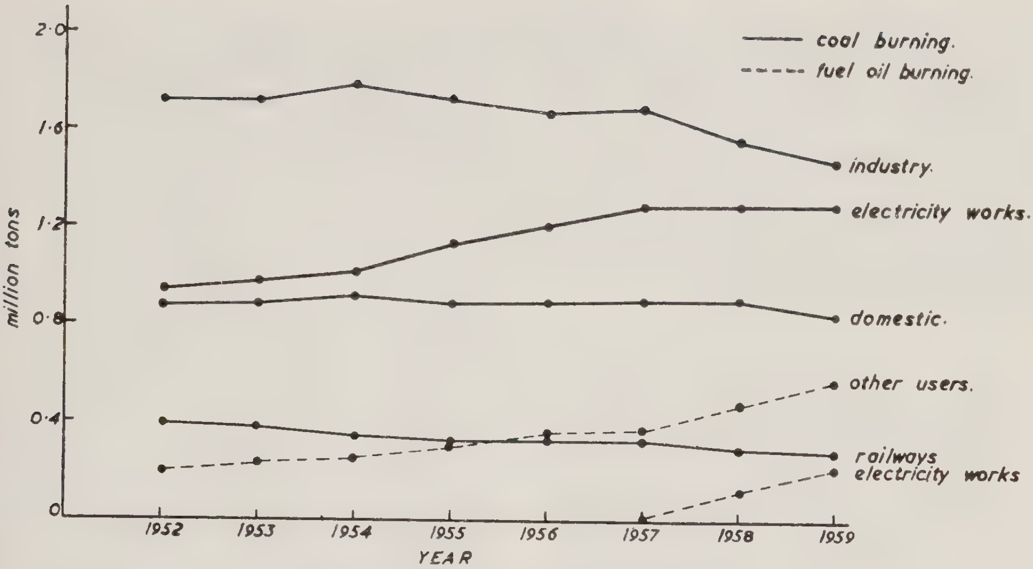

Fig.3 Trends in emission of sulphur dioxide by groups of consumers in Great Britain, 1952 - 1959

filters in operation in Great Britain, and since almost all of them are in urban areas the results quoted apply only to such areas. The same applies to results for sulphur dioxide given in the next section.

Concentrations of Sulphur Dioxide near Ground Level throughout the Country

Trends in sulphur dioxide concentrations have been determined in exactly the same way as those for smoke, using the data obtained by the daily hydrogen peroxide method. The results are given in Tables 5 and 6 which correspond precisely with Tables 3 and 4. All the measurements were taken at sites where smoke measurements were also made, but the numbers of instruments in each set in Table 6 are rather less than the corresponding numbers in Table 4 as at some sites smoke alone was measured.

Table 5 suggests that there has been no marked increase or decrease in pollution over either of the periods at the sites concerned.

Two clear-cut simple conclusions can be drawn from the data in Table 6. The first is that the peaks in 1955-6 and 1958-9 and the dip in 1959-60, which were the salient features of the data for smoke in Table 4, are reproduced here for sulphur dioxide in just as pronounced a manner. This strongly suggests that these effects are caused by different weather conditions superimposed on whatever steady basic trend in pollution there may be as a result of changes in the industrial and domestic patterns of heating. The second conclusion is that, apart from these effects of weather, there is no detectable increase or decrease in the level of pollution by sulphur dioxide over the period concerned.

The Ratio Smoke/Sulphur dioxide

A comparison of the data in Tables 2, 4, and 6 shows that the ratio of smoke to sulphur dioxide in the air at ground level is about unity whereas they are emitted in the ratio of about 0·4. This is generally taken as proof that sulphur dioxide is removed from the atmosphere by natural

TABLE 5

Trends in Concentrations of Sulphur Dioxide throughout the Country

Period	*Number of gauges*	*Percentage of total showing*		
		Increase	*No change*	*Decrease*
1952-60	28	20	60	20
1955-60	75	10	70	20

processes at a greater rate than smoke but it may equally well be that a much larger proportion of the total smoke than of the sulphur dioxide is emitted at a low level, for example, from domestic chimneys, and is therefore less effectively dispersed into the upper air, and remains to make a larger contribution to pollution near the ground than an equal emission of sulphur dioxide from higher chimneys.

TABLE 6

Average Sulphur Dioxide Concentrations throughout the Country

Year	*Number of gauges*	*Sulphur dioxide, microgrammes/cubic metre*
1952-3	28	242
1953-4	28	220
1954-5	28	220
1955-6	28	233
1956-7	28	211
1957-8	28	220
1958-9	28	260
1959-60	28	220
1953-4	29	214
1954-5	29	217
1955-6	29	231
1956-7	29	205
1957-8	29	215
1958-9	29	253
1959-60	29	217
1954-5	35	225
1955-6	35	237
1956-7	35	211
1957-8	35	220
1958-9	35	253
1959-60	35	217
1955-6	75	240
1956-7	75	215
1957-8	75	222
1958-9	75	247
1959-60	75	211
1956-7	103	208
1957-8	103	211
1958-9	103	233
1959-60	103	200
1957-8	146	208
1958-9	146	233
1959-60	146	200
1958-9	219	225
1959-60	219	191

Be this as it may, the fact remains that the effect of weather conditions on the accumulation of pollution near ground level should be much the same for smoke and sulphur dioxide once these substances have entered the lower layers of the atmosphere so that a consideration of changes in the ratio smoke/sulphur dioxide should enable conclusions to be drawn that are independent of changes in weather from year to year, and may be taken to refer to "standard" weather conditions.

Data on this ratio are given in Table 7 for the period 1955-60.

The observed ratios of concentrations decreased almost steadily from 1955-6 to 1959-60, showing no trace of the peaks and dips that were so prominent in the data for the individual concentrations, which confirms the view that these apparently erratic variations were due to the effects of changing weather conditions. The steady drop in the ratio smoke/sulphur dioxide is therefore left as the basic trend, and it is seen that it corresponds very closely with the steady change in the ratio in which these pollutants were emitted over the period.

Emission and Ground-level Concentration of Smoke and Sulphur Dioxide in London

The consumption of fuels and the emission of smoke and sulphur dioxide by domestic heating, electricity works and industry in the London area over the same period 1952 to 1959, are given in Tables 8 and 9 and are shown graphically in Figures 4, 5 and 6.

There are two omissions from Table 8. The first is the amount of coal consumed by factories burning less than 1,000 tons each a year. By analogy with the country as a whole this amount is probably about 5 per cent. of the total figure for industry and will make an inappreciable contribution to pollution. The other omission concerns the amount of fuel oil burned to heat commercial premises and has probably increased from about 60 thousand tons in 1953 to 300 thousand tons in 1959. This made a contribution to the emission of sulphur dioxide of about 10 thousand tons in 1959.

The emission of smoke in the London area decreased by about 41 per cent. between 1952 and 1959, due mainly to a big drop in domestic coal consumption. The emission of sulphur dioxide increased by 30 per cent. during the years 1952 to 1955, but then decreased, the amount

TABLE 7

The Ratio Smoke/Sulphur Dioxide 1955-60

	Smoke and SO_2 in the air				*Smoke and SO_2 emitted*
	Smoke *µg/cu. m.* (105 *sites*)	SO_2 *µg/cu. m.* (75 *sites*)	*Smoke/SO_2*		*Smoke/SO_2*
1955-6	233	240	0·97	1955	0·44
1956-7	211	215	0·98	1956	0·43
1957-8	198	222	0·89	1957	0·39
1958-9	208	247	0·84	1958	0·36
1959-60	166	211	0·79	1959	0·34

TABLE 8

Consumption of Fuels in the London Area from 1952 to 1959
Thousand tons

	1952	1953	1954	1955	1956	1957	1958	1959
Coal								
Domestic	3,600	3,700	3,639	3,470	3,227	2,634	2,400	2,012
Electricity works ..	4,100	4,133	4,465	4,789	5,133	4,754	4,500	3,976
Industry	1,200	1,822	1,820†	1,828	1,718	1,621	1,600	1,220
Coke								
Domestic	400	500*	629	535	507	439	700	476
Oil								
Domestic	small	26	31	30	50	50	100	127
Electricity works ..	small	41	85	114	104	52	164	332
Industry								
Diesel and gas oil ..	small	25	26	24	26	27	33	33
Fuel oil	small	220	227	416	453	457	597	685

* actual figure not available; assumed 500,000 tons.
† actual figure not available; assumed 1,820,000 tons.

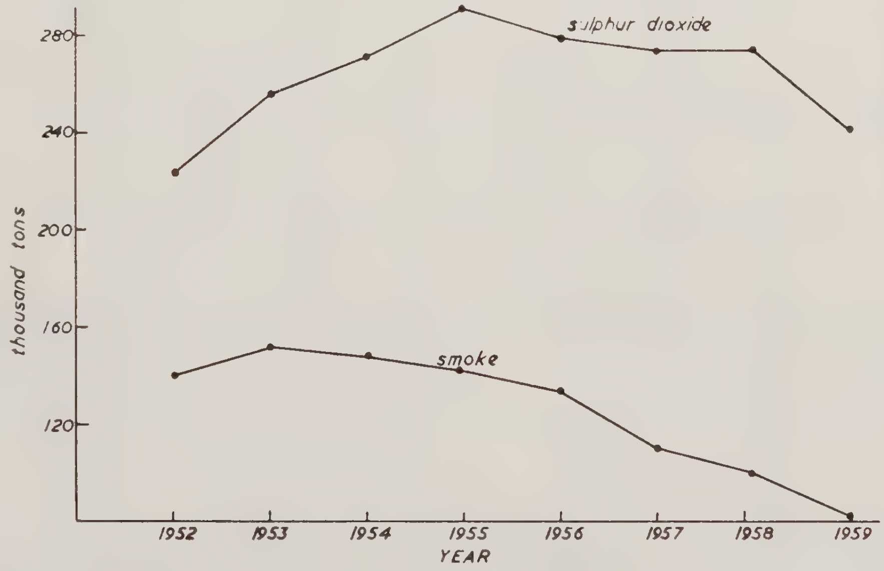

Fig. 4 Trends in emission of smoke and sulphur dioxide in London, 1952-1959

Table 9

Emission of Smoke and Sulphur Dioxide in the London Area, 1952-1959

Thousand tons

	1952		1953		1954		1955		1956		1957		1958		1959	
	Smoke	Sulphur dioxide	Smoke	Sulphur dioxide	Smoke	Sulphur dioxide	Smoke	Sulphur dioxide	Smoke	Sulphur dioxide	Smoke	Sulphur dioxide	Smoke	Sulphur dioxide	Smoke	Sulphur dioxide
Coal																
Domestic	126	86	130	89	127	87	121	83	113	77	92	67	84	62	70	51
Electricity works	small	95	small	93	small	107	small	121	small	117	small	122	small	113	small	103
Industry	14	32	22	49	22	49	22	49	21	46	18	47	16	46	12	35
Coke																
Domestic	nil	10	nil	12	nil	15	nil	13	nil	12	nil	11	nil	18	nil	12
Oil																
Domestic	nil	small	nil	small	nil	small	nil	small	nil	small	nil	small	nil	small	nil	small
Electricity works	small	small	small	small	small	small	small	small	small	small	small	small	small	small	small	small
Industry																
Diesel/gas	nil	small	nil	small	nil	small	nil	small	nil	small	nil	small	nil	small	nil	small
Fuel oil	nil	small	small	13	small	14	small	25	small	27	small	27	small	36	small	41
Total	140	223	152	256	149	272	143	291	134	279	110	274	100	275	82	242
Smoke/Sulphur Dioxide	0.63		0.59		0.55		0.49		0.48		0.40		0.36		0.34	

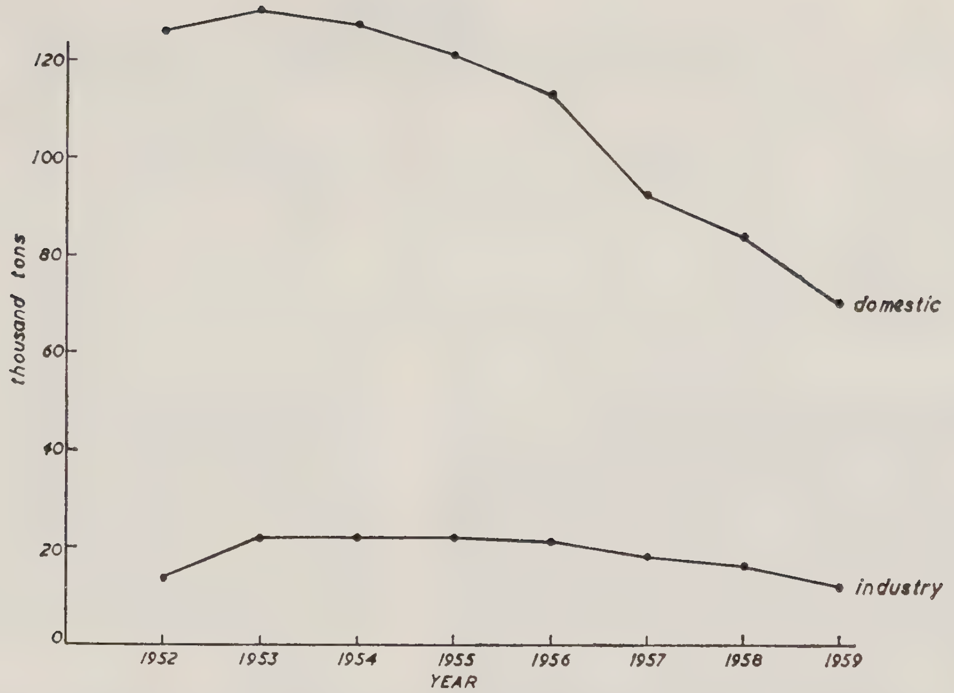

Fig. 5 Trends in emission of smoke by groups of consumers in London, 1952-1959

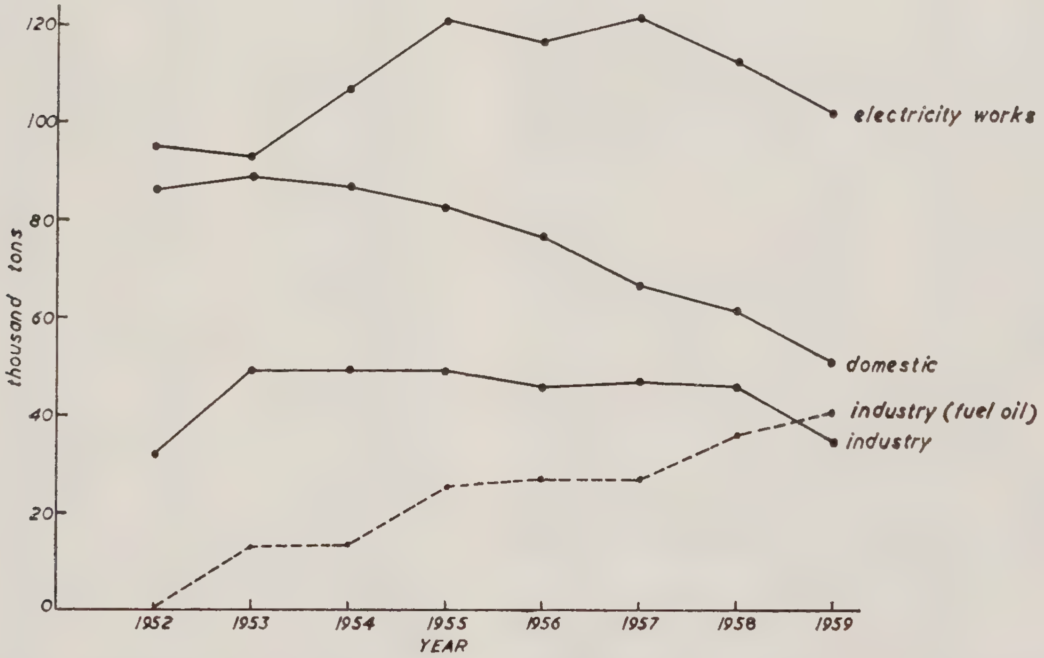

Fig. 6 Trends in emission of sulphur dioxide by groups of consumers in London, 1952-1959

emitted in 1959 being only 13 per cent. more than in 1952 (there would have been a greater increase if gas washing were not practised at Bankside generating station).

This pattern is different from that in the country as a whole. There was a much bigger decrease in smoke emission in London after 1956 than in the rest of the country. The sulphur dioxide emission increased more rapidly than elsewhere till 1955 and then decreased whereas over the country as a whole emission continued to increase until 1958.

It was of particular interest therefore to compare trends of ground-level concentrations in London with those elsewhere, and Tables 10, 11, 12 and 13 were prepared to correspond to Tables 3, 4, 5 and 6.

The data in Table 10 show, in marked contrast to the position for the country as a whole, as given in Table 3, that in London smoke has been decreasing at the

TABLE 10

Trends in the Concentration of Smoke in London

Period	*Number of gauges*	*Percentage of total showing*		
		Increase	*No change*	*Decrease*
1952-60	4	—	25	75
1955-60	32	5	10	85

great majority of the sites at which measurements are being made.

The data for smoke concentrations in Table 11 show the same peak for 1954-5 as the rest of the country, which, as has been seen, was probably due to unfavourable weather conditions. Since that date, however, the decrease in smoke concentrations in London has been so rapid that the unfavourable weather in 1958-9, which caused a sharp peak in pollution for the rest of the country, in London did no more than slow up the rate of decrease. The weather in London was just as unfavourable as in the rest of the country as the peak in the concentration of sulphur dioxide was as pronounced in that year as in the country as a whole. This spectacular decrease in smoke during the period under review has brought the concentration of smoke in London down to the urban average for the country as a whole. It corresponds closely to the decrease in domestic coal consumption in the area and shows what excellent results can be achieved by vigorous smoke-control action.

The position with regard to sulphur dioxide is not so satisfactory.

Table 12 shows that at the 29 sites where measurements have been made since 1955 there is hardly any sign of sulphur dioxide concentrations decreasing over the period 1955-60.

As mentioned above, the data for sulphur dioxide given in Table 13 show the same peaks at 1955-6 and 1958-9 and the dip for 1959-60 as the country as a whole, due to weather, but no basic trend, either upwards or downwards, can be detected. This leaves the concentration of sulphur dioxide in London nearly 20 per cent. higher than the urban average for the country. The absence of a significant downward trend is particularly disappointing as the emission of sulphur dioxide decreased by 14 per cent. over the period 1955-9.

This result, considered in conjunction with Table 9 and Figure 6 can only mean that the fall in emission of sulphur dioxide

TABLE 11

Average Smoke Concentrations in London

Year	*Number of gauges*	*Smoke, microgrammes/ cubic metre*
1952-3	4	300
1953-4	4	255
1954-5	4	252
1955-6	4	310
1956-7	4	245
1957-8	4	222
1958-9	4	222
1959-60	4	178
1953-4	4	255
1954-5	4	252
1955-6	4	310
1956-7	4	245
1957-8	4	222
1958-9	4	222
1959-60	4	178
1954-5	8	219
1955-6	8	248
1956-7	8	200
1957-8	8	195
1958-9	8	189
1959-60	8	152
1955-6	32	287
1956-7	32	239
1957-8	32	222
1958-9	32	211
1959-60	32	168
1956-7	50	244
1957-8	50	217
1958-9	50	213
1959-60	50	167
1957-8	59	214
1958-9	59	210
1959-60	59	164
1958-9	62	211
1959-60	62	162

TABLE 12

Trends in the Concentration of Sulphur Dioxide in London

Period	*Number of gauges*	*Percentage of total showing*		
		Increase	*No change*	*Decrease*
1955-60	29	15	65	20

TABLE 13

Average Sulphur Dioxide Concentrations in London

Year	*Number of gauges*	*Sulphur dioxide, microgrammes/cubic metre*
1952-3	5	400
1953-4	5	336
1954-5	5	325
1955-6	5	320
1956-7	5	280
1957-8	5	302
1958-9	5	320
1959-60	5	268
1953-4	5	336
1954-5	5	325
1955-6	5	320
1956-7	5	280
1957-8	5	302
1958-9	5	320
1959-60	5	268
1954-5	7	330
1955-6	7	322
1956-7	7	277
1957-8	7	302
1958-9	7	311
1959-60	7	277
1955-6	29	288
1956-7	29	254
1957-8	29	265
1958-9	29	291
1959-60	29	248
1956-7	43	245
1957-8	43	257
1958-9	43	277
1959-60	43	237
1957-8	51	254
1958-9	51	274
1959-60	51	231
1958-9	53	265
1959-60	53	231

from the domestic burning of coal is more than offset by the low-level emissions from the sharply increasing use of fuel oil in industry. It again tends to exonerate electricity generating works because if they contributed much to the sulphur dioxide near ground level in London a fall in the sulphur dioxide concentration should have been observed in the last few years.

Conclusions

The main interest in a study of trends is the possibility of using them as a basis of estimates of pollution likely to occur in the near future.

For the country as a whole, the first question to be asked is whether the slow but steady decrease in smoke that has occurred over the past few years is likely to continue. There is good reason to believe that the major source of smoke is the burning of coal for domestic heating (see Williams, F. P., paper to this Conference), so the question is reduced to one about probable domestic coal consumption. Both the introduction of smoke control areas under the Clean Air Act, and changing social habits, which are leading to more and more houses being left unoccupied and unheated during the day, have as a result the replacement of coal by gas and electricity, and these factors together with the arrangements that are being made for the production of more solid smokeless fuels should certainly enable the present improvement to be continued. The fact remains however that for very many years to come coal must continue to be the main source of domestic heat. This is a consequence of the impossibility of storing electricity and gas from summer to winter and the difficulty of making solid smokeless fuels without obtaining at the same time a large amount of gas. It would be quite uneconomic to set up works to meet the winter load and allow them to stand idle during the summer. Taking the whole country into consideration, therefore, there seems little prospect of greatly accelerating the reduction of smoke in the near future, but the spectacular reductions achieved in London show what can be done by special efforts in particularly affected districts.

Prediction of pollution by sulphur dioxide is rather more difficult. The steady rise in the emission of sulphur dioxide was halted last year but it would not be safe to assume that it has reached its peak. With the estimated expansion of industry for the near future it will be very surprising if the emission of sulphur dioxide does not increase again. However, even if it does, the fact that pollution by sulphur dioxide near ground level did not increase over a period when the emission was increasing shows that if adequate steps are taken to disperse the chimney gases—high chimneys, suitable siting of works—the concentration of sulphur dioxide near ground level need not increase and might, with careful control, even be expected to decrease slightly. But the data for London presented in this paper should be taken as a warning. Emissions of sulphur dioxide from the large coal-burning plant and from domestic heating have been decreasing sharply but the good effect of this at ground level has been more than outweighed by the increased emission from industrial oil-burning plant. Although, in the last five years, the total emission has decreased, the ground level pollution has not. This alone is proof that the dispersion from the chimneys of the new oil-burning plant is inadequate.

The data, both for the whole country and for London, indicate that emissions from high chimneys, as at the newer electricity generating works, make relatively little contribution to pollution near the ground, which is determined to a large extent by emissions from the lower chimneys, whether domestic, for smoke, or industrial and domestic for sulphur dioxide.

In conclusion, the authors would like especially to thank Mrs. B. D. Gooriah for her work on the pollution data for 1959-60 and on the sulphur dioxide by the hydrogen peroxide method for the whole of the period under review. By using these latter results instead of those obtained by the less certain lead dioxide method, the conclusions have been put on a much firmer basis than was possible when the paper was presented at the Conference.

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POLLUTION LEVELS IN CITIES

By

*F. P. Williams**

Summary

A study of air pollution measurements provided by the D.S.I.R. Co-operative Investigation of Atmospheric Pollution shows that the concentration of pollution is independent of the size of towns. Smoke pollution at any point depends on the density of the population, and on the coal consumption per head of population, in a relatively small area surrounding that point. For 68 sites in the Yorkshire and London areas, a close correlation was found between smoke concentration and the domestic coal consumption per square mile, with a highly significant correlation coefficient of + 0·647. The domestic contribution to smoke pollution measured at low level is estimated at over 80 per cent. for most urban areas.

Introduction

IT is commonly believed that large towns are dirtier than small ones, and, since industry is usually concentrated in large towns, industry is usually blamed. The present paper summarizes a study made of the measurements provided by the D.S.I.R. Co-operative Investigation of Atmospheric Pollution, and shows that, as far as smoke is concerned, the observed pollution is not connected in any way with the size of the town, and that nowadays, almost all the smoke comes from domestic fires.

Pollution and Population

The first stage of this investigation was to examine the relationship between the population of a town and the pollution observed in it. Population data was taken from the Municipal Yearbook.

Pollution by Smoke

All the yearly average smoke concentrations available for 1957-58, some 200 in number, were plotted against the population of the towns concerned. It was found that the smoke concentrations varied apparently indiscriminately throughout the whole population range.

Thus Figure 1 shows that towns with a population of 10,000 can have a pollution range of 50 to 500 μg/cu.m, while at the other extreme, towns with a population of half a million have a similar wide range of 60 to 800 μg/cu.m. This wide variation in pollution exists not only between different towns of the same size; it also exists within individual towns, as can be seen in Table 1.

In Figure 1, the individual London boroughs were taken as separate towns and their respective populations used. If London had been considered as one large urban community and its overall population plotted against the smoke concentrations observed, then in a city with an overall population approaching ten millions, the smoke concentrations would still vary from only 70 to no more than 430 μg/cu.m with an average figure of slightly less than 200 μg/cu.m. Thus, at the two extremes, a population of ten thousand produces smoke concentrations of 50 to 500 μg/cu.m while a population of ten million still only produces concentrations of 70 to 430 μg/cu.m.

In effect, it can be said that, no matter what the size of the town, in nine cases out of ten the smoke concentrations observed will lie somewhere between 70 and 350 μg/cu.m.

It is sometimes considered that the centre of a town, in addition to its own pollution, also receives pollution blown in from the suburbs, so that the pollution near a town centre would be higher than in other areas of the town. Measurements do not support this view. Table 2 shows that in London and Sheffield the centre of the town is no

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* Warren Spring Laboratory, D.S.I.R.

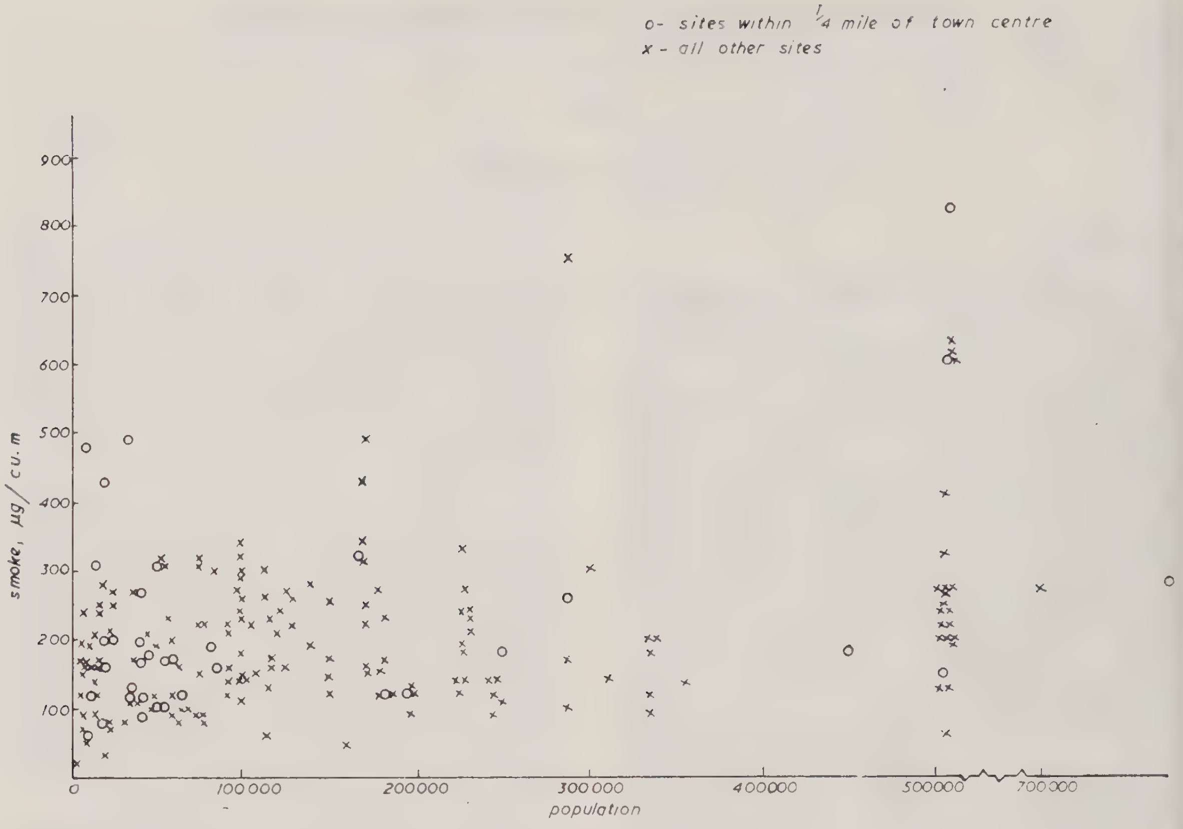

Fig. 1 Smoke and population, 1957-8

TABLE 1

Variation of Smoke Pollution within the same Town

Town	*Smoke concentration, μg/cu.m*	
	Lowest	*Highest*
Ilford	120	230
Leeds	190	820
London (Metropolitan Area)	70	430
Newcastle-upon-Tyne . .	170	750
Sheffield	60	410
Southampton	90	130

dirtier than its surroundings; nor is there a significant fall in smoke pollution within the town, as one moves outwards from the centre, until the outer suburbs are reached. Further reference to Figure 1 shows that, at sites within $\frac{1}{4}$ mile of a town centre, there is no increase in smoke pollution with the size of the town and also that there is the same wide variation in pollution among towns of the same size.

Pollution by Sulphur Dioxide and Deposited Matter

A similar study was made of measurements of sulphur dioxide and deposited matter (insoluble deposits only).

Once again, the graphs in Figures 2 and 3 speak for themselves—an apparently indiscriminate spread of pollution throughout the whole population range.

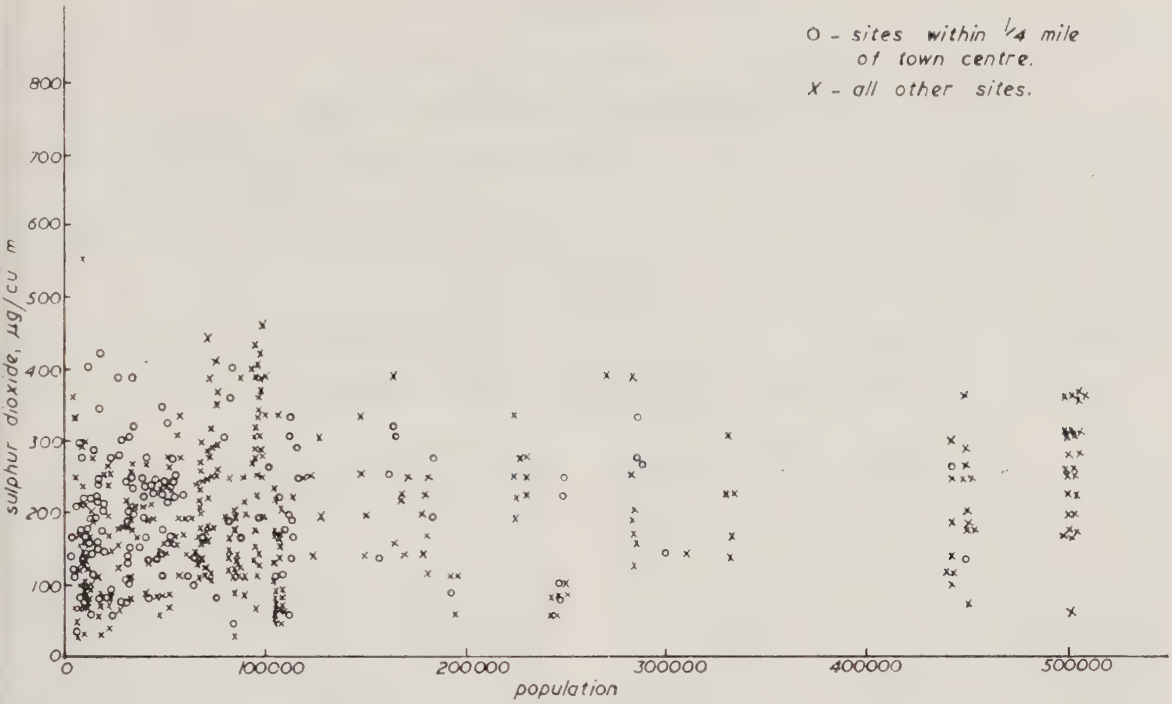

Fig.2 Sulphur dioxide and population, 1957-8

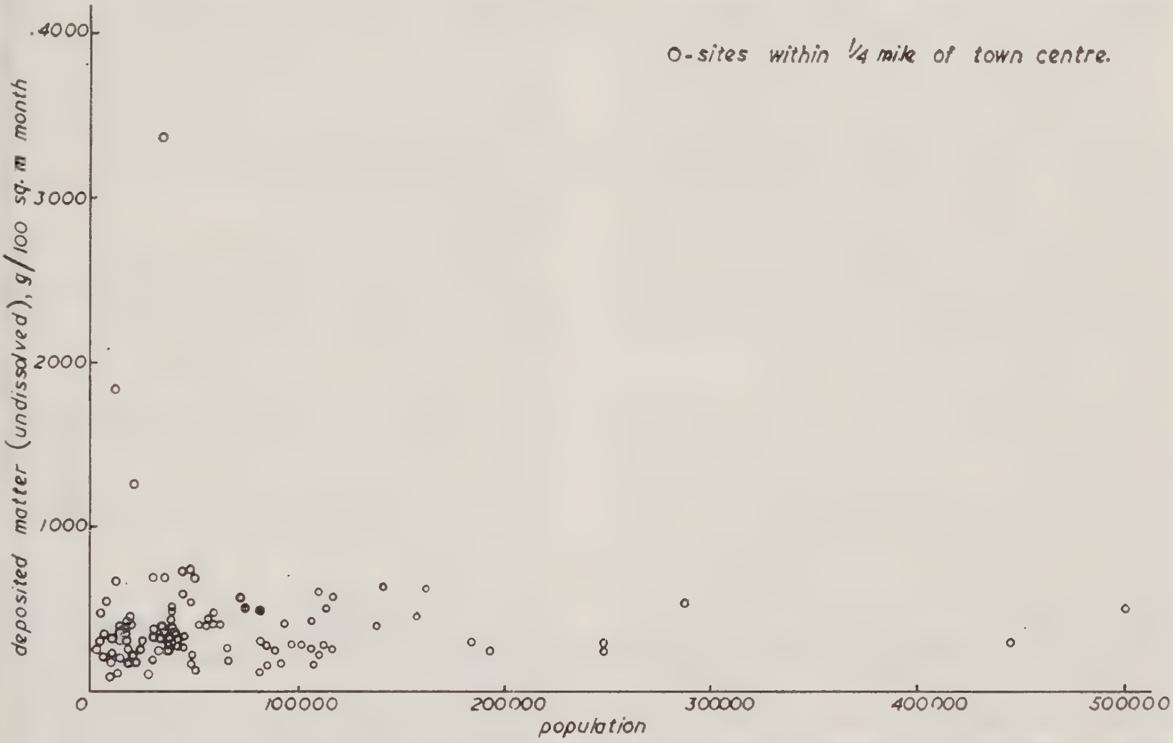

Fig.3 Deposited matter (undissolved) and population, 1957-8

Summary

Air pollution is no respecter of the size of towns. Large towns obviously have larger areas of pollution than small towns, but the actual concentrations are not necessarily any higher. Sites near the centre of a town are shown to be no more polluted than other sites further away, nor does the pollution at the centre of a town increase with its size.

From the wide variations in the concentrations of air pollutants observed at different sites within the same town, and within towns of similar size, it would appear that air

TABLE 2

Variation of Smoke Concentrations
With Distance from the Centre of a Town

Distance from centre of town, miles		0	½	1	2	3	4	5	6	7	8	9	10
Average smoke concentration, μg/cu.m	Sheffield	150	230	260	260	250	130	—	—	—	—	—	—
	London	—	260	210	200	230	250	260	170	150	150	160	170

pollution is affected by conditions peculiar to a small local area, and not by the larger area of the town as a whole. As such, the air pollution problem can be just as serious in any small town as in any large town. Conversely, reduction in emission in a relatively small area may be expected to bring a local reduction in pollution.

Pollution and Population Density

The importance of local conditions on the incidence of air pollution was also observed by Wilkins and Pindard in their paper to this Conference in 1958[1], in which they showed that the low smoke concentrations in the City of London's Smokeless Zone were not appreciably affected by variations in wind directions from heavily polluted areas outside.

This suggests that, for normal conditions, it is not a sideways drift near ground level, but the removal of smoke upwards by atmospheric turbulence, which is by far the most important factor in its dispersal. Thus, the pollution at any given spot in a town depends, primarily, on the amount of pollution put into the air within a small area around it, say a ¼ to ½ mile radius, and only to a small degree on drift from areas outside.

The next step, then, was to examine the effect that the local population density, within a small area around a site, had on the pollution observed.

Pollution by Smoke

In reply to a questionnaire sent to all Local Authorities, who had provided a complete set of smoke observations for 1957-58, information was obtained on the number of dwellings and types of buildings within a half mile radius of each of their smoke filter sites. From these replies, it was possible to make a comparison of 37 sites in Yorkshire with 31 sites in London; in all the sites selected, the smoke measurements had been assessed by photo-electric equipment. The number of dwellings within each half mile radius has been converted to a population figure by multiplying it by the national average factor of 3·6. The results quoted are for 1958-59, but similar results were obtained for the year 1957-58 and 1959-60.

Figure 4 shows that when the population per square mile increases, smoke pollution increases also. The correlation coefficients for the London and Yorkshire areas are 0·756 and 0·524 respectively, both being significant at the 0·1 per cent. level. The correlation coefficient for the combined areas is 0·369, significant at the 0·3 per cent. level.

It is interesting to note that the relationship differs in the London and Yorkshire areas, the increase in pollution with the increase in the population density being much greater in the Yorkshire area. The domestic coal consumption per head in Yorkshire is approximately three times that in London and this has been taken into account in Figure 5. Now, the combined relationship for the London and Yorkshire areas, based on the domestic coal consumption per square mile, is very much improved and with a correlation coefficient of 0·647, is very highly significant.

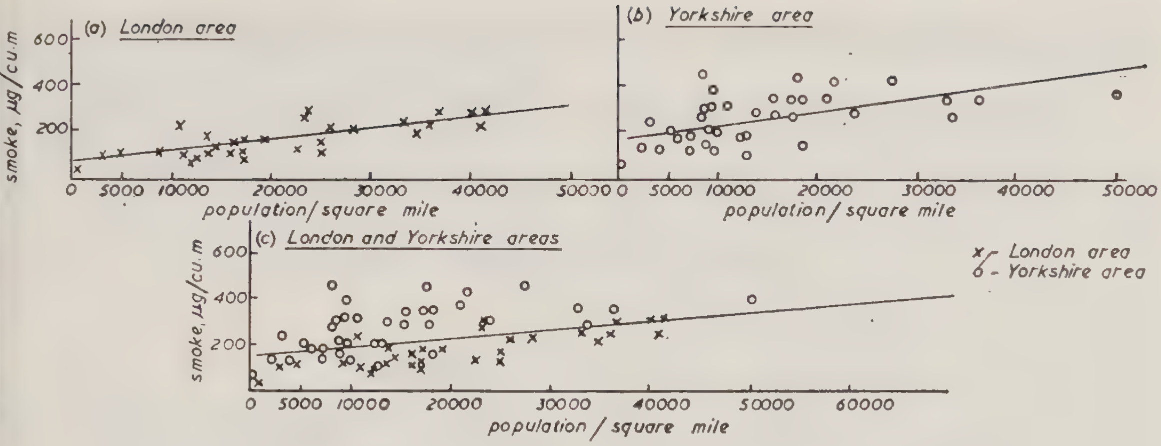

Fig. 4 Smoke and density of population around sites, 1958-9

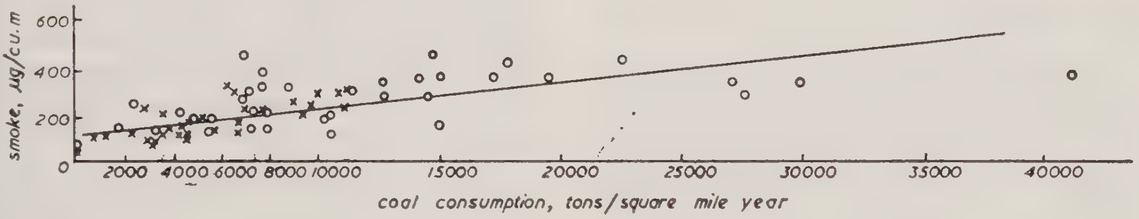

Fig. 5 Smoke and domestic coal consumption around sites, 1958-9

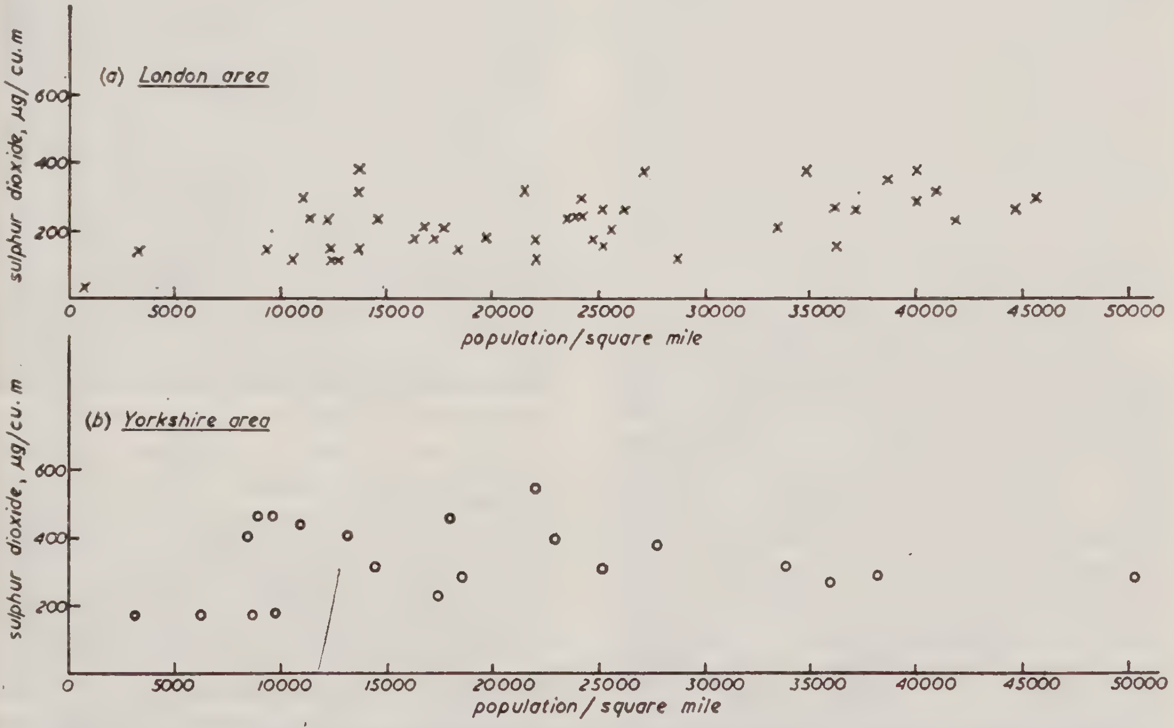

Fig. 6 Sulphur dioxide and density of population around sites, 1958-9

Pollution by Deposited Matter and Sulphur Dioxide

No further work has been done as yet on the distribution of deposited matter and only a brief examination made of the relation between sulphur dioxide and the density of population, the results of which are shown in Figure 6. No statistical analysis has been made, but the apparent lack of any strong relationship is perhaps to be expected. The more efficient combustion processes in industry, while reducing or eliminating smoke emissions, have little or no effect on the emission of oxides of sulphur.

Domestic Contribution to Smoke Pollution

Calculations, based on relative domestic and industrial fuel consumption and combustion efficiencies, put the domestic emission of smoke between 65[2] and 90 per cent.[3] The low level and low velocity of domestic emissions, as compared with the higher level and higher velocity emissions of industry, would lead one to expect an even higher percentage domestic contribution to the concentration of smoke observed at ground level. This would raise the above estimates, based on emissions, to, say, between 80 and 98 per cent. These estimates are based on the fuel consumption for the country as a whole; in many areas with little or no industry, the domestic emission will be 100 per cent., but this will have the effect of reducing the proportionate domestic emission in the areas with industry.

Thus, the domestic contribution to low level smoke pollution in the average urban area with some industry would probably be between 70 and 90 per cent., and this estimate is borne out by the smoke concentrations actually measured. From the measurements and the strong linear relationship obtained between the smoke concentrations observed at low level and the domestic coal consumption figures in the areas around the smoke filter sites, that is, ignoring the industrial coal consumption, a domestic contribution of 80 to 85 per cent. is indicated. An independent examination of the results from 160 sites during the winter and summer of 1959 indicated an average winter domestic contribution of 83·5 per cent., with two out of three sites having a domestic contribution of over 80 per cent.

Conclusions

The evidence produced shows that large towns are not necessarily dirtier than small towns. Smoke pollution at any point is a much more local matter than was previously thought, depending on the density of population, and its coal consumption, in a relatively small surrounding area, and as such, the inhabitants of a small town may well be exposed to smoke concentrations as high as, or higher than, those found in large towns.

The highly significant relationship found to exist between smoke pollution and the domestic coal consumption per square mile, that is, with no adjustments made to compensate for industry, indicates just how important the contribution of domestic chimneys is to low level smoke pollution. The strength of this relationship would indicate an average domestic contribution of at least 80 per cent. in most urban areas, a percentage which would rapidly increase in areas with little or no industry.

The work described in this paper forms part of the programme of the Warren Spring Laboratory of the Department of Scientific and Industrial Research and is published by permission of the Director. The figures are Crown Copyright and published by permission of the Controller, H.M. Stationery Office.

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THE MEASUREMENT OF ATMOSPHERIC POLLUTION: THE ACCURACY OF THE INSTRUMENTS AND THE SIGNIFICANCE OF THE RESULTS

By

S. R. Craxford, D. W. Slimming and E. T. Wilkins

Summary

The performance of the instruments in common use in this country for the measurement of atmospheric pollution is being investigated and this paper is a progress report, presenting data on their reliability and accuracy, and on possible errors inherent in them. It is intended as an interim guide to the interpretation of the results obtained with these instruments.

THERE is in Great Britain a long record of efforts to measure atmospheric pollution leading up to the present system with its co-operative organization which is now under the aegis of the Department of Scientific and Industrial Research. The results gathered over many years and throughout the country have formed a basis of fact for local clean air legislation and ultimately for the nation's Clean Air Act. This marks the completion of one stage in the use of measurement: the next stage is to assess the effects of recent legislation and administrative action so that the direction in which further progress is needed may be determined. For this purpose, as also for investigations into the effect of air pollution on health, there is need for a more accurate knowledge of the capabilities of the instruments used and a more precise handling of the data obtained. As a first step in this direction the inherent limitations of the present methods of measurement are being investigated at the Warren Spring Laboratory.

The same concern for increasing the precision of measuring equipment and procedure is being felt in other countries. About three years ago a Working Party was set up by the Organization for European Economic Co-operation to investigate the possibility of standardizing the instruments used for the measurement of air pollution throughout Europe and beyond, and all three of the present authors have taken part as British representatives. The Working Party is naturally concerned with errors in the present methods and the significance of the results obtained by their use.

The British Standards Institution is also reviewing the performance of instruments used for the measurement of atmospheric pollution. The deposit gauge which is in common use has been defined by a British Standard (B.S. 1747) since 1951, and this specification is now being revised by a Committee of the Institution in the light of recent experience. Another of their committees is also considering the possibility of standardizing methods of determining smoke and sulphur dioxide in the atmosphere. Here again standardization must be preceded by taking stock of the latest available information.

In view of the importance of the problem of efficient measuring techniques as well as the widespread interest in it exemplified above, the present interim account of the first stages of the relevant investigations in progress at the Warren Spring Laboratory is being published as a guide to users and potential users of the various types of instrument concerned, to assist them in the interpretation of their results.

The British Standard Deposit Gauge

Particles of grit and dust are emitted from boiler plant and furnaces, from plant involving the handling of powdered materials and from domestic fires, and after spreading to a greater or less distance from their sources they are deposited on the surface of the earth. The exact amount of material so deposited on unit area can be measured, but only under extremely specialized conditions (Carey, W. F., Int. J. Air Pollution, 1959, **2,** 1). Pollution by grit and dust is a constant nuisance to town dwellers and the need was felt many years ago and still exists, for a comparative method of measuring the rate of deposition which would be simple to install and operate and would enable the dustiness of different localities to be compared even though the absolute amount of deposition could not be determined. The gauge which was ultimately developed into the British Standard Deposit Gauge was devised to meet this requirement and an immense amount of data has been collected by its use both in this country, where there are more than 1,100 such gauges in continuous operation, and abroad.

The material collected by the deposit gauge consists of matter falling directly into it, subject to the effects of micro-turbulence round the rim, matter raised from the ground and blown into it, soluble matter brought down in solution in rain, insoluble matter brought down by the scavenging action of rain, less matter blown out of it by the wind. Lucas (Lucas, D. H., J. Inst. Fuel, 1957, **30,** 623) compared results obtained with a normal deposit gauge with those from one where the bowl was kept half full of water and estimated that on the average about half the total deposit is blown out of the normal gauge by the wind. As the proportion blown out will always depend on whether the gauge is sited in a sheltered or an exposed position the utmost caution must be observed in comparing results at different places. The same factor also affects the amount of dust raised by the wind that is collected by the gauge though the fact that the gauge is placed some 4 feet above ground level helps to avoid dust from the ground.

The purely arbitrary nature of this type of gauge was emphasized by a recent investigation at Greenwich in which five different varieties were compared and the deposit collected was found to vary by a factor up to and sometimes exceeding two according to the details of the geometry of the bowl.

Keeping the arbitrary nature of its readings in mind, it is, however, generally considered that the British Standard Deposit Gauge gives a useful arbitrary measure of the amount of deposition which is valuable in making local surveys and in assessing changes at any place. This being so, a knowledge of the reproducibility of the measurements is important in order to be able to estimate the probable accuracy of any given result before going on to consider its significance.

The reproducibility was first examined at Kew Observatory by exposing two gauges 15 feet apart for four years and the differences in deposit due to casual errors was found to be appreciable (see *Measurement of Air Pollution*, London, H.M.S.O., 1958, p.11). This investigation has recently been repeated over a period of two years for pairs of gauges at three sites in different parts of London and one in a rural area in Scotland. Detailed data for two of these pairs of gauges are given in Table 1.

Inspection of this Table gives an indication of the reproducibility of individual readings. For the lower rate of deposit (Thorntonhall) differences tend to be proportionally greater than for the larger amounts of deposit at Greenwich.

In the Annual D.S.I.R. publication *The Investigation of Atmospheric Pollution*, (London, H.M.S.O.) giving summaries of the results of the D.S.I.R. Co-operative Survey, data for deposit

TABLE 1

Comparison of Amounts of Insoluble Material Collected by Two Pairs of Adjacent Deposit Gauges

Deposits in milligrammes per square metre per day, mg./sq. m d (equal to 10 times the more familiar grammes per 100 square metres per month divided by the number of days in the month).

	Thorntonhall Nr. Glasgow		*Greenwich*	
	1st Gauge	*2nd Gauge*	*1st Gauge*	*2nd Gauge*
1955				
June ..	52	54		
July ..	23	28		
August..	40	30		
September	19	14	410	311
October	14	15	399	430
November	13	16	321	309
December	27	16	476	465
1956				
January	15	16	394	372
February	27	27	596	580
March	19	19	442	434
April ..	58	49	401	420
May ..	23	25	369	376
June ..	—	—	527	545
July ..	16	22	360	336
August..	15	23	366	366
September	21	21	418	372
October	7	13	444	431
November	9	13	495	411
December	15	12	—	—
1957				
January	19	16	444	395
February	12	14	412	406
March	18	17	314	95
April ..	24	23	404	344
May ..	27	27	618	462
June ..	41	43	319	371
July ..			404	366
August..			418	371
September			320	305

gauges are given as six-monthly and yearly averages. The corresponding averages have been obtained for the data in Table 1, for the periods indicated by the rulings in the Table, and are given in Table 2. This table shows that if averages over a period are considered, the differences between the two gauges sited near together are very much less. It is such averages that are given in the Annual Reports.

A more precise statement of the amount of variation between duplicate gauges for the sites referred to in Table 2 and for two other sites in the London area are given in Table 3.

TABLE 2

Comparison of Average Data for Insoluble Material Collected by Two Pairs of Adjacent Deposit Gauges
Deposits in mg./sq. m day

	Thorntonhall		*Greenwich*	
	1st Gauge	*2nd Gauge*	*1st Gauge*	*2nd Gauge*
1st 6 months	27	26	433	411
2nd 6 months	28	25	411	413
3rd 6 months	14	17	421	352
4th 6 months	24	23	414	370
1st 12 months	28	26	422	412
2nd 12 months	19	20	418	361

Averages for the whole 24 month period are given for the four sets of sites in Table 3.

The data show that at the third site there was a consistent difference between the gauges, indicating that although they were close to each other they were receiving different deposits. At the other sites the mean differences over the two years and the standard deviations indicate that there was no real difference between the amounts of deposits in the two gauges. Assuming that a gauge is properly sited and is not set to catch deposits from chimneys immediately overlooking it, it may be concluded that for practical purposes individual readings have an accuracy of about ±20 per cent.

The whole question of the satis-

TABLE 3

Insoluble Matter Collected by Four Pairs of Adjacent Deposit Gauges
Average Data for a 24 month Period

Site	*Mean rate of deposit, mg/sq.m day*	*Mean percentage difference between the two gauges*	*Standard deviation*
1	404	6	10
1	171	6·5	28
3	56	36	43
4	23	5·5	21

TABLE 4

Sets of Deposit Gauges in Line

Percentage deviation from mean result

	Gauge 1	Gauge 2	Gauge 3	Gauge 4	Gauge 5	Gauge 6
1st site, 23 readings Insoluble matter	−3	+2	+3	−2		
2nd site, 21 readings Insoluble matter	+1	+3	+3	0	−4	−3

factory siting of deposit gauges is one fraught with difficulties and this, together with the associated question of how far a deposit gauge is representative of the area surrounding it, is now being examined. For this investigation two open spaces surrounded by housing and industry but with no works chimney or other major source of pollution immediately overlooking them were chosen. In other words the sites were as uniformly exposed to pollution as one could judge in advance. There was space at the first site to set up four gauges in line at 75 foot intervals and at the second six gauges in line at 100 foot intervals. The mean results are given in Table 4.

It will be seen that at both sites the results for insoluble matter differed from gauge to gauge by only two or three per cent. This means that the search for uniform sites had proved quite successful and that any one point on either of these sites might well have been selected as representative of the whole site. In other words, for these favourable circumstances a gauge can be representative of quite an extensive area about it. It must be emphasized that the sites were chosen as open spaces having no emitters of dust or grit immediately overlooking them. The deposited matter was therefore the finer material that is carried some little distance before deposition. The intense local nuisances caused by deposited matter generally arise from the coarse grit that falls in the immediate vicinity of its source, and gauges set to collect such deposits must of necessity be installed at sites that are far removed from ideality in the sense of this investigation, and such gauges are probably only characteristic of a very limited area indeed.

The position may be summarized by saying that deposit gauge measurements are necessarily arbitrary and the accuracy of their relation to the “ real ” figure is uncertain. The reproducibility is reasonable so that on a favourable site the measurement is representative of a fair area. On sites where the pollution is subject to sharp variation the area represented by a gauge is very limited.

It will have been noticed that the discussion, and the data in Tables 1 to 4, have been restricted to the insoluble fraction of the deposited matter. This has been done deliberately as the relationship between the soluble fraction and atmospheric pollution as normally understood is extremely obscure.

The Smoke Filter

As the weight of smoke in air, even the air of heavily polluted cities, is too small to be conveniently determined by direct weighing of filters, all the methods for its routine determination are based on estimating the staining of a filter paper and applying calibration data for relating this to the weight of smoke on the filter.

Originally, the stain was compared with an arbitrary scale of shades produced by Owens and the concentration of smoke deduced from a calibration by Clark which showed that if the stain was equivalent in darkness to the Owens Shade Number N the weight of smoke on the filter paper, in microgrammes per square centimetre, was RN where the calibration factor R is a constant, equal, according to Clark, to 8·0.

In the D.S.I.R. instructions on the use of smoke filters (see *Measurement of Air Pollution*, London, H.M.S.O., 1958, p.25), it was recommended that the rate of flow of air through the filter should always be about 70 cu. ft./day,

TABLE 5

Effect of rate of flow of air on the calibration factor of smoke filters

Diameter of filter, in.	*Total rate of flow of air, cu. ft./day*	*Rate of flow of air per unit area of filter paper, cm^3/cm^2 sec.*	*R/R^1*
1·0	20	1·3	1·00
	40	2·7	0·99
	70	4·6	1·05
	120	7·8	1·23
	240	15·7	1·56
	360	23·3	1·67
0·5	71	18·3	1·63
1·0	71	4·6	1·08
2·0	64	1·0	1·00

ut that the size of the filter should be hosen according to the amount of moke in the air so that the stain prouced is neither too light nor too dark r precise comparison with the scale f shades or accurate assessment with reflectometer. Filters of diameters in., 1 in. and ½ in. were recommended.

Experiments done three years ago r the O.E.E.C. Working Party howed that if three smoke filters of iameters ½, 1 and 2 in. were run in arallel with an air flow of about o cu. ft./day through each, the results, alculated by the above formula, ppeared to depend markedly on the iameter of the filter. This was conirmed by subsequent experiment, and r the three diameters quoted above R varied in the ratios 1·63/1·08/1·00.

Since the rate of flow of air through ach filter was the same the rate per quare centimetre of filter paper and ence the linear velocity, varied in the atios 16/4/1 for the three filters espectively. This suggests that the ffect described in the previous pararaph may be due to the change in inear velocity, because it is reasonable o suppose that if the velocity of the air hrough the filter is increased the articles of smoke penetrate further and re less effective in darkening the urface of the paper. If this is so, the etermination of the effect of the air elocity is important as many types of utomatic smoke filters are now beoming available, all working with ifferent air velocities, which are also ery much greater than those corresponing to the velocities in the D.S.I.R. in. and 2 in. filters working with 70 cu. ft. of air per hour.

Tests with a 1 in. diameter filter were then carried out at a series of different rates of flow of air, to confirm this view, and the results are given in Table 5 together with the earlier results for the other filters. The rate of flow of air is given in cubic centimetres per square centimetre of filter paper per second, and the calibration factor R as a ratio R/R^1 where R^1 is the calibration factor for the lowest rate of flow used, i.e., for a rate of 1 cm^3/cm^2 seconds.

The results are shown graphically in Figure 1 which enables smoke readings obtained at different rates of flow to be compared.

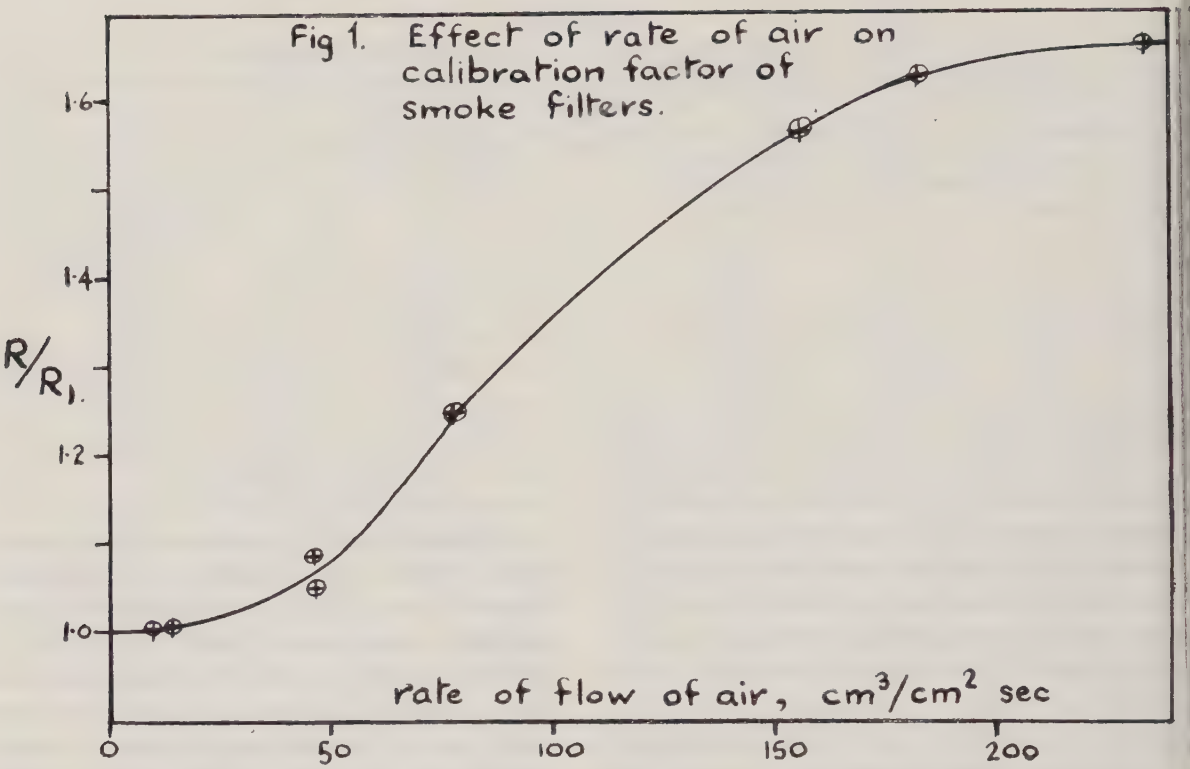
It should be noted that all the results quoted refer to Whatman No. 1 filter paper with the smoke collected on the smooth side.

The consistency of smoke determinations is indicated by the results of a typical series of 14 duplicate measurements which gave mean values of 324 and 317 μgm/m³ with a mean percentage ratio of 100·5 for which the standard deviation was 7·7. The reproducibility of the results was thus quite good.

Extensive work is in progress at the Warren Spring Laboratory on the correlation of the blackness of the smoke shown with the weight of smoke per unit area of filter paper, but this will be reported elsewhere.

Sulphur Dioxide—Hydrogen Peroxide Method

As is well known, the hydrogen peroxide method measures the net gaseous acidity of the air, but since



under normal circumstances sulphur dioxide is the preponderating contributing constituent, the method gives a good approximation to the concentration of sulphur dioxide. As a preliminary step to a comparison of the results obtained by it and by other more complicated but specific methods for sulphur dioxide (which will be reported later) the effect of the smoke filter, through which the air is usually passed before entering the hydrogen peroxide bubbler, was examined.

The first of these trials was carried out in an industrial area of East Greenwich where the general level of pollution was high. Duplicate bubblers, one with and one without a smoke filter, were run for two separate periods of about three weeks' duration each. In the first series the loss of sulphur dioxide varied from 1 to 18 per cent. with an average loss of 9 per cent. During this period the weather was mainly dry and very cold. In the second series the loss varied from 7 to 34 per cent. with an average loss of 16 per cent. During this period the weather was not so cold but more humid.

A further series of measurements was carried out in a lightly polluted area at Thorntonhall outside Glasgow. In this case the results varied widely, the losses ranging from −11 per cent. to +56 per cent. with a mean value of 15 per cent. As a check on the accuracy of the sampling and analysis a further bubbler without a filter was run at the same time. The mean value of the difference between the two identical bubblers without filters was under 1 per cent. and was not statistically significant, thus affording evidence of the genuineness of the other difference.

Two further series of measurements were then carried out in the south of Glasgow in an area of moderate pollution between industrial and residential districts. In this instance both the filter plus bubbler and the bubbler alone were run in duplicate, and agreement between identical pairs was very good, again giving evidence of the genuineness of the difference between the readings of a bubbler alone, and one preceded by a filter.

Two further series of measurements were finally carried out at the original site in Greenwich in which the bubbler not preceded by a filter was run in duplicate. Again the agreement between the two measurements without the filter was excellent strengthening the evidence for the genuineness of the observed reduction due to the filter.

The results of these trials are summarized in Table 6 from which it appears that the previous estimate of the average reduction due to the use of the filter (1 to 4 per cent.) is an under estimate. The individual variations, which include instances where the use of the filter actually increased the result, reinforce the view that the actual factor is specific to any one day and place and is probably dependent on the concentrations of fine alkaline and/or acid particles (lime, cement, sulphuric acid mist, acid-smuts etc.) as well as on any retentive capacity of the filter paper for sulphur dioxide.

The reproducibility of results from the hydrogen peroxide instrument depends to some extent on the manner in which the instrument is used. If it is used alone the reproducibility is excellent but the introduction of a smoke filter in advance of the bubbler, as is the general practice, tends to reduce the consistency of the results a little. Thus to quote the results of a typical series of experiments, 19 duplicate readings were carried out without smoke filters in the lines; they gave mean values of 254·2 and 254·0 μgm/m^3 with a mean percentage ratio of 100·9 for which the standard deviation was 4·8. On the other hand 18 duplicates with smoke filters in front of the bubblers gave mean values of 56·4 and 55·2 μgm/m^3 with a mean percentage ratio of 103·6 and a standard deviation of 7·9. This significantly higher standard deviation is an indication of the slight additional variability introduced by the insertion of the smoke filter in the line. However, both with and without the filter, the reproducibility of the results is of a high order.

Sulphur Dioxide—the Lead Dioxide Method

The lead dioxide method measures the rate at which sulphur dioxide (plus some other sulphur compounds) reacts with a lead dioxide surface prepared under defined conditions. It was devised as an aid in an investigation on the rate of decay of building materials, presumably on the ground that both processes had this at least in common, that they depended on the rate of reaction of atmospheric sulphur dioxide with a solid surface. For many years it has been used in this and other countries to provide an approximate indication of pollution by sulphur dioxide on an empirical scale; this extension of the original use of the method has become widespread largely on account of the extreme simplicity of the technique.

The reproducibility of the results obtained by the lead dioxide method has been studied using duplicate instruments mounted 15 feet apart at three sites in London and one at Thorntonhall (in the country near Glasgow), and also with two instruments, one mounted directly above the other, at Thorntonhall. The results are summarized in Tables 7 and 8.

Inspection of the Tables shows the differences that may be found between two sites as near together as 15 feet.

Correlation with the results of the

TABLE 6

Effect of a Smoke Filter on the Hydrogen Peroxide Method for Sulphur Dioxide

Source	*No. of results in set*	*Mean value of reduction due to filter, per cent.*	*Standard deviation*	*Range in which 19 out of every 20 values of the reduction due to the filter are likely to appear*
Greenwich 1956				
1st set	19	9·4	4·1	7·5 to 11·5
2nd set	19	16·4	2·7	15 to 18
Thorntonhall 1957	49	14·8	11·4	11 to 18
Glasgow 1959				
1st set	7	10·9	7·0	4·5 to 17
2nd set	19	7·7	19·7	−1·5 to 17
Greenwich 1959				
1st set	19	4·1	3·1	2 to 6
2nd set	20	3·8	1·7	2 to 5·5

TABLE 7

Reproducibility of Results obtained with Lead Dioxide Instruments

The two instruments at each site were 15 ft. apart. Data are given in conventional rates of sulphation, milligrammes SO_3 per day per 100 sq. centimetres of standard lead dioxide surface.

	Fulham Palace Garden		*Tate Gallery*		*City of London School*	
	1st Gauge	*2nd Gauge*	*1st Gauge*	*2nd Gauge*	*1st Gauge*	*2nd Gauge*
1955						
May	1·16	1·05	1·04	1·10	2·28	2·29
June	1·49	1·40	2·48	2·41	2·36	2·15
July	0·97	0·96	1·40	1·37	1·49	1·65
August	1·13	1·16	1·83	1·81	1·86	1·67
September	0·59	0·57	2·43	2·40	2·12	2·05
October	1·29	1·24	3·59	3·79	4·27	4·10
November	2·41	2·36	4·30	4·34	4·95	4·62
December	2·05	1·94	4·75	4·71	4·97	4·74
1956						
January	2·45	2·32	5·43	5·42	6·27	5·79
February	3·13	3·08	4·80	4·88	5·76	5·77
March	2·88	2·65	4·10	4·08	5·48	5·28
April	2·21	2·23	3·73	3·47	3·99	3·61
May	0·97	0·95	2·11	2·10	2·08	2·19
June	0·53	0·52	1·89	1·93	1·66	1·63
July	0·71	0·71	2·19	1·57	1·77	1·87
August	0·59	0·61	2·26	2·15	1·54	1·59
September	1·04	1·14	2·58	2·62	2·50	2·37
October	1·42	1·37	3·69	3·75	4·53	4·20
November	2·60	2·40	4·40	4·30	5·40	5·40
December	1·85	1·82	4·57	4·64	4·96	4·86
1957						
January	1·80	1·71	4·28	4·51	4·84	4·79
February	1·56	1·55	4·23	4·25	4·82	4·60
March	1·51	1·44	3·65	3·69	4·54	4·34
April	1·80	1·22	2·54	2·53	3·38	3·29
Average	1·59	1·52	3·26	3·24	3·66	3·54

TABLE 8

Reproducibility of Results obtained with Lead Dioxide Instruments
at Thorntonhall, near Glasgow

The first instrument was 15 ft. from the other two, the second was mounted immediately below the third. Data are given in conventional rates of sulphation, milligrammes SO_3 per day per 100 square centimetres of standard lead dioxide surface.

	1st Gauge	*2nd Gauge*	*3rd Gauge*
1955			
June	0·295	0·276	0·267
July	0·266	0·291	0·278
August	0·301	0·312	0·312
September	0·192	0·192	0·189
October	0·322	0·239	0·244
November	0·490	0·425	0·432
December	0·563	0·540	0·568
1956			
January	0·613	0·554	0·532
February	0·898	0·762	0·787
March	0·641	0·637	
April	0·465	0·440	0·405
May	0·211	0·182	0·198
June	0·362	0·317	0·314
July	0·203	0·175	0·205
August	0·241	0·255	0·268
September	0·319	0·309	0·311
October	0·277	0·263	0·264
November	0·416	0·385	0·399
December	0·338	0·333	0·325
1957			
January	0·472	0·400	0·410
February	0·588	0·547	0·544
March	0·393	0·364	0·365
April	0·411	0·401	0·432
May	0·407	0·416	0·398
June	0·383	0·307	0·302
Average	0·403	0·373	0·365

hydrogen peroxide method was examined for seven pairs of instruments distributed throughout the country and so arranged in each instance that the air inlet of the hydrogen peroxide instrument was within a few inches of the lead dioxide cylinder. Most of the results by the hydrogen-peroxide method were obtained by local authority personnel; most of the lead peroxide cylinders were prepared and analysed by the D.S.I.R. Results are given in Table 9.

The results of this trial indicate that the factor by which the lead dioxide reading must be multiplied to give the concentration of sulphur dioxide varied from month to month at any given site and from site to site for any given month. The yearly means for each of the sites varied from 63 to 172 and the average value for all the sites was 112. This factor was used to convert the individual lead dioxide readings to concentrations, and the concentrations so obtained varied from about one-half to four times the value observed by the hydrogen peroxide method. About 50 per cent. of the calculated results were within ±25 per cent. of the observed value and over 80 per cent. were within ±50 per cent. Treating the yearly averages in the same way gave concentrations differing from the values obtained by the hydrogen peroxide method by something in the range ±50 per cent. All these figures refer to the trial summarized in Table 9, and while other comparisons at other sites might well give data differing in detail, there is no reason to suppose that the general picture of the variations would be different.

Since the lead dioxide method depends on measuring a rate of reaction the results should, on theoretical grounds, be dependent on the concentration of sulphur dioxide in the air, the temperature, the wind velocity, and possibly the humidity and other factors affecting the state of the lead dioxide surface, such as the exact details of the preparation of the surface. The results given in Table 9, showing no simple connection between concentration of sulphur dioxide and the lead dioxide reading, are therefore to be expected. However, knowing the underlying reasons, and the order of magnitude of the effects, it is not difficult to define the value of the method for various purposes.

In the first place, considering readings at any one site, it is clear that they should not be used to give an indication of changes in concentration of sulphur dioxide from one month to another. Comparisons of one year with another are also not very precise, although they may have been useful in defining areas of gross pollution. If however trends over a number of years are considered, for example, by a comparison of one five-year average with the next or of

TABLE 9

Comparison of the Lead Dioxide and the Hydrogen Peroxide Methods at the same Sites

Values are given for the concentration of SO_2 by the H_2O_2 method, in microgrammes per cubic metre. divided by the rate of sulphation of lead dioxide, in milligrammes SO_3 per day per 100 square centimetres PbO_2,

	Greenwich	*Hornchurch*	*Lambeth*	*Leyton*	*Nottingham*	*Teddington*	*Thorntonhall*	*Average*
1956								
August ..	69	189	123	52	172	34	34	97
September	63	135	120	132	103	74	37	94
October ..	114	—	120	175	137	106	75	120
November	109	—	96	132	92	—	69	100
December	146	163	140	160	109	135	73	132
1957								
January ..	66	129	126	103	86	80	66	94
February	71	209	169	155	60	103	60	117
March ..	63	160	198	135	63	94	69	112
April ..	95	183	120	158	54	112	112	120
May ..	106	241	160	140	192	92	94	146
June ..	95	153	140	172	186	57	57	115
July ..	86	138	149	83	95	29	29	86
Average ..	92	172	137	132	112	83	63	112

five-year running averages, the variations due to wind, weather etc., tend to become small and the measurement of sulphur dioxide more precise; the five-year average has long been recommended by the D.S.I.R. for this purpose.

In any district of limited size, for example, a city, or the area surrounding a particular source such as a power station, the method can give a precise picture of the pattern of pollution and is likely to continue to be of great value for this purpose.

If all the lead dioxide cylinders for any month are made up by the same operator at the same time, errors due to variable reactivity of the cylinders will be reduced to a minimum, and it is a reasonable assumption that in the limited area of the survey they will be exposed to the same weather conditions —wind, humidity, temperature—so that the rate of sulphation should bear the same relation to the concentration of sulphur dioxide for each. The pattern of concentrations so obtained should therefore be valid, although the absolute values for each month can only be obtained by comparison with data from a hydrogen peroxide apparatus at one or two points in the survey.

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REPORT ON THE B.S. COKE

By

J. O. Cooke and F. J. Eaton***

Summary

An outline of the experience of the Gas Industry in the production and marketing of coke to B.S.3142 and of the premium quality domestic smokeless fuels such as Cleanglow and Phimax.

THE Beaver Committee recognized that the main substitute for house coal must be solid smokeless fuels and that increased coke production at gas works would be necessary. The Report, issued in November, 1954, states (para. 78) that " as initially we look to coke as the main solution we must make clear that when we speak of coke we mean a high quality free burning fuel that will be completely satisfactory to the domestic consumer when used in modern appliances." To ensure a satisfactory quality the British Standards Institution were recommended to prepare a specification to which Gas Boards and other producers would supply.

B.S.I. Standard Experimental Stages

A representative B.S.I. Committee first met in May 1955 and adopted as a basis for discussion the Gas Council 1951 standard for open fire coke. The problems were to determine to what extent existing plant and coal supplies could meet the target specification and from the test data obtained to determine and evolve a method of expressing the consistency of quality. This question of consistency was considered to be essential to a quality specification; eventually a method based on " Quality Control " was adopted but it required many thousand tests by the Gas Boards and the National Coal Board to decide what was a reasonable consistency.

B.S.I. Standard Published

By the end of 1958 the experimental stages were completed. 35 of the largest gas coke plants were working to the specification which was published in September 1959. This first issue of the standard defines size limits, maximum moisture content and a fire performance test which controls ease of ignition and burnability. The cokes supplied to the new standard will be of the consistent quality specified at the point of dispatch from the producers' works only. The ultimate aim is that eventually the purchaser should have the independent assurance of the B.S.I. that he is buying coke complying with the standard. Experience both in the operation and in the control of the standard product through the various channels of distribution indicates that this aim can be achieved but more experience is necessary before this can become a reality.

The main problem here is moisture control on which much experimental work has been done. This shows that, contrary to popular belief, coke in storage out of doors is not a good absorbent for water, indeed the air-filled cellular structure is an excellent repellant and water from rain or snow or even from complete immersion remains largely as surface water. The high moistures to which publicity is given arise from the bagging after rain of coke taken mainly from the surface pieces which roll down the heap. The remedy is to dig into the heap and allow the outer pieces to " air " dry. This handling problem is recognized in the foreword to the British Standard Specification and replacement of a delivery is made if a complaint of high moisture is confirmed.

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New Standard for Closed Appliance Fuels

The B.S.I. Committee stimulated by a recommendation of the Peech Committee referred to later in this paper has now begun the preparation of a British Standard for cokes for domestic boilers, open and closed stoves and cookers. This presents entirely different problems from those dealt with in open fire fuels and Gas Boards with other producers have started large scale experimental work in this field.

Peech Committee Report: Market Needs for Smoke Control Areas

The Report of the Ministry of Power Committee* set up to enquire into the availability and suitability of solid smokeless fuels and plans for future production and also the adequacy of present arrangements and future plant for distribution in connection with requirements for the implementation of the Clean Air Act estimated that by 1965 an additional $5\frac{1}{2}$ million tons of solid smokeless fuel would be needed to that used today of which in order to satisfy consumer preference at least two million tons would be for specially reactive fuels capable of burning in either improved open fires or old fashioned grates. The Committee recommended inter alia that all coke used in improved fires should be made to the new British Standard and that this coke should not be supplied for use on old-fashioned grates and concluded that all Gas Boards in collaboration with the National Coal Board should consider producing or increasing the production of specially reactive fuels.

High Quality Cokes for Modern Open Fires

The regular production of high quality domestic coke by Gas Boards which followed the widespread adoption of continuous production control at gas works created a marketing problem in the disposal of the product in the domestic trade at prices which covered the additional costs of the regular control testing, bearing in mind that identification of specification coke by the user was essential. The Gas Industry had marketed high quality open fire cokes under proprietary brand names but this lapsed during the war. The Gas Light & Coke Company, as early as 1909, had made a carbonized fuel " Charco " and two years later a similar product under the name of " Carbo." These were followed by the marketing a few years before the war of " Cleanglow " a fuel produced for use with the special coke burning fires which had been developed by the London and Counties Coke Association and which were the forerunners of the modern improved open fire. A semi-coke called " Gloco " was also produced experimentally. Similarly other large gas undertakings had produced named high quality domestic cokes, the South Metropolitan Gas Company with their " Metrocoke," the Edinburgh undertaking with " Grancole " and the Liverpool Gas Company with " Dryco."

Prompted by these experiences Gas Boards accordingly decided to market the new high quality cokes under brand names. " Gloco " was adopted for high quality continuous vertical domestic coke introduced by the North Thames Gas Board in March 1959, and in May of the same year the Eastern and the South Western Boards began the sale of " Gloco " in their areas. At the same time the South Eastern Gas Board put " Sebrite " on the market, a new name being used as this high quality coke is being made in a different type of retort, is dissimilar in appearance and has a higher bulk density than " Gloco." In November 1959, the Southern Gas Board entered the market with " Gloco." Scotland and the Northern Gas Board started to sell it in their areas in May 1960, and the North Western and East Midlands Gas Boards will market it in October 1960. The North Eastern and West Midlands Gas Boards are already making high quality coke to the new standard and have plans for marketing it under the brand name when the demand justifies t but certainly before the end of the heating season 1960-61.

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* Cmnd. 999—1960.

Very considerable tonnages of “ Gloco ” and “ Sebrite ” then will be on the market in most parts of the country for the 1960-61 heating season. The launching of new products is both complex and delicate. The balance of production and the needs of the markets call for careful handling by producers if they are to avoid shortages or being left with large unsold stocks at the end of each heating season. Both “ Gloco ” and “ Sebrite ” are finding favour with domestic users and production is being kept in phase with demand, the closest attention being paid to requirements arising from the establishment by local authorities of new smoke control areas.

Specially Reactive Solid Smokeless Fuels

The Peech Committee concluded that many users in Smoke Control Areas prefer to use specially reactive fuels such as “ Cleanglow ” or “ Phimax ” rather than the premium quality standard open fire cokes and that all Gas Boards not yet producing such fuels should consider the feasibility of doing so. “ Cleanglow ” made from low rank coals by a modified carbonizing process in continuous vertical retorts was placed on the market by the North Thames Gas Board in October 1956 and by the East Midlands Gas Board in January 1960. It is currently in production also by the Eastern and North Eastern Gas Boards and will be placed on the market by them at the beginning of the 1960-61 heating season. “ Phimax ” was placed on the market by the North Western Gas Board in January 1957. Although both “ Cleanglow ” and “ Phimax ” sell at higher prices than coke they have rapidly become popular with the public. The tonnage now available is already substantial and plans are in hand to increase production.

This short paper has dealt with the production by the Gas Industry of special high quality solid smokeless fuels for the domestic market under proprietary brand names which can be readily identified and named by domestic users. Coke is a term applied to a whole family of fuels with widely differing characteristics depending upon the class and quality of coal from which it is made, the plant in which the coal is carbonized, the conditions of carbonizing and the reactivity, sizing, bulk density and moisture of the coke made. Without means of identifying the different types produced the whole range of cokes has become associated in the public mind with a hopelessly confused scale of values which has turned many users away from coke. The development of the new proprietary brand names for fuels for use with particular appliances and the recognition by users of these fuels will do much to right this situation and to ensure consistent supplies of high quality coke in the domestic market.

SMOKE CONTROL IN ACTION: THIRTEEN YEARS' EXPERIENCE IN BRADFORD

By

*D. G. Wilson, A.C.I.S., A.C.W.A.**

Summary

In Bradford since 1946 it has been the policy of the Local Authority to prohibit the emission of smoke by tenancy agreement in all its postwar housing estates. There is consequently a history of 13 years operation of smoke control. In 1959 a sample survey was conducted to find out the views of householders. A very large percentage of households were found to rely on open fires for space and water heating. Gas ignition was used in most cases. There was a high level of satisfaction with the heating arrangements and with coke as a fuel. Most obtained their supplies from a merchant's roundsman. Although there was general approval for coke on grounds of cleanliness, heat value and minimum trouble, paradoxically about 30 per cent. said they would return to coal.

TO the layman in most parts of the country the concept of smoke control is still new and is commonly thought to date from the passing of the Clean Air Act in 1956 or possibly from the publication of the Beaver Report in 1954. Yet in some districts the Clean Air Act merely gave statutory force to a policy which had been voluntarily adopted by the local authority in recognition of the problem of polluted air.

In Bradford since 1946 it has been the policy of the local authority to prohibit the emission of smoke from its own newly built property and to this end all post-war corporation housing estates were by tenancy agreement made " smokeless zones " from the commencement of their occupation. Today, in sharp contrast to the many localities where smoke control is still experiencing its teething troubles (not its birth pangs!), in Bradford ther is a solid history of 13 years operatio of smoke control in working clas dwellings where now over 9,000 tenant are regularly using smokeless fuel.

The collective experiences an opinions of these people must clearl form a valuable guide to publi reaction to the change from burnin bituminous coal to smokeless fue Consequently in the Autumn of 195 a survey was carried out on a rando sample of 539 dwellings—approxi mately 1 in 17 of all houses on th post-war estates. The informatio obtained has been divided up into nin sections and is appended below. Th percentages in each section do no always total 100 owing to overlap incomplete answers, etc.

I. Domestic Circumstances

	Age Group	%
Estimated age of person interviewed	16—24	
	25—35	33
	36—45	33
	Over 45	22
Average age of person interviewed	40 years	
Whether housewife goes out to work	Full time	22
	Part time	22
	Not at all	56
Number of persons living in dwelling	1—2	1
	3—4	4
	5—6	2
	7 and above	
Average number living in dwelling	4·3	

74 per cent. of the persons inter viewed were estimated to be betwee the ages of 25—45 and most of th remainder were over 45. The averag was approximately 40. Some 65 pe cent. lived in family units of 3— persons.

Approximately half of the wives wer working either full or part-time an to preserve the true random character of the sample evening follow-up call were made where first and second daytime calls were unsuccessful. Substitute addresses were permitted only if the original addressee could not be contacted after several day and evening calls.

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* Coke Officer, North Eastern Gas Board.

II. Appliances

Type of fire in main living room:	%
Open fire	44
Open fire with back boiler	51
Heating stove	4
Gas fire	1
Electric fire	2
Paraffin heater	—

In 95 per cent. of the dwellings visited the principal form of space heating in the main living room was the open fire with or without back boiler. These properties included some large through-rooms as much as 22 feet in length and of 2,350 cubic feet in volume and which were clearly beyond the capacity of a single open fire to heat adequately in cold weather. Yet only 4 per cent. had installed at their own expense some form of heating stove.

The incidence of gas and electricity for the main space heating load was almost negligible.

III. Ignition

Method of lighting solid fuel:	%
Integral gas ignition	87
Blade gas poker	7
" Nico " type gas poker	2
Wood and paper	4

Gas ignition was the accepted means of lighting the fire and no comment or criticism was encountered under this heading.

IV. Fuel

Type of fuel burnt before living in smokeless zone	%
Coal	95
Coke	5
Fuels used now:	
Coke	98
Coalite	4
Paraffin Gas Electricity	1
Period over which smokeless fuel has been used:	
1 year	14
2 years	13
3 years	12
4 years	10
5 years or longer	46

These figures indicate the radical change in the pattern of fuel usage brought about by the compulsion to use smokeless fuels.

The opinions later recorded are given added weight by the relatively long periods during which smokeless fuels are shown to have been used.

V. Space Heating Service

Opinion of present space heating arrangements:	%
Good	71
Adequate	15
Poor	13
Incidence of overnight burning:	
Regularly	1
Occasionally	7
Never	91

The general level of satisfaction with the space heating service was good, but some measure of complaint could be traced to the large size of some of the rooms which were being heated by a single 16 inch fireplace.

A very low incidence of regular overnight burning was noted. Little advantage appeared to be gained by having the fire burning all night and the speed and ease of daily ignition did not encourage this habit.

VI. Water Heating

	Summer %	*Winter* %
Method of water heating:		
Fire back boiler	51	54
Independent domestic boiler	43	44
Gas	2	—
Electricity	5	2

Opinion of present water heating arrangements:	%
Good	91
Adequate	5
Poor	3

Water heating was mainly shared between fireback and independent domestic boilers. Few people used gas or electricity even in the summer months.

There was a very high level of satisfaction with the water heating service which was often remarked upon.

VII. Supply of Solid Fuel

Solid fuel supplied by:	%
Coal/Coke Merchant	95
Gas Board	5
Whether a satisfactory delivery service is obtained?:	
Yes	99
No	1
Method of ordering:	
In advance by post	4
In advance by 'phone	1
In advance by call at Order Office	14
Wait for roundsman to call	80
Quantity bought at a time during winter:	
1 cwt. or less	5
2 cwts.	64
3 cwts.	13
4 cwts.	9
5 cwts. or more	9
Any reasons why less than 4 cwts. is bought at a time:	
Limited storage	13
Convenience	57
Financial outlay	27

95 per cent. bought their solid fuel from a merchant and only 5 per cent. from the Gas Board. 80 per cent. waited for a weekly " rounds " service and 14 per cent. ordered at a local merchants' office (mainly the Co-op).

There was a large proportion of fuel deliveries carried out by small merchants who have entered the trade in recent years and now cater exclusively for the sale of solid smokeless fuels in the Bradford area.

99 per cent. of persons interviewed were satisfied with their fuel delivery service and many praised it.

VIII. Specific Questions about Coke

Whether considered cleaner than coal:	%
Yes	77
No	8
About the same	12
Whether considered hotter than coal:	
Yes	74
No	14
About the same	9
Whether considered less trouble than coal:	
Yes	59
No	14
About the same	24
Opinion of coke costs compared with coal:	
The same	43
Cheaper	16
Dearer	35
Any difficulties in using coke:	
Fumes	5
Recovery	4
Lighting	8
Dust	6
Ventilation Flying Shale Some appliance fault	2

It is accepted that some of the questions in this section were not entirely without bias but difficulty was encountered in obtaining completely objective information on these matters.

It was particularly difficult to obtain information about comparative fuel costs as many tenants had not burned coal for several years and had no yardstick to measure coke costs against. There was however some measure of feeling that coke was expensive " for what it is " and most tenants were clearly price conscious.

IX. Smokeless Estates

Whether in favour of Smokeless Estates:	%
Yes	91
No	5
Don't know	4
Whether easier to keep house and clothes clean living on a Smokeless Estate:	
Yes	87
No	7
Don't know	5
After using smokeless fuel whether would ever want to go back to using coal:	
Yes	31
No	68

If answer "Yes" to last question, what are reasons for preference for coal:	% *of "Yes" replies*
Appearance	68
Cost	12
Warmer	6
Healthier	3
Other reasons	3
No reply	8

In the answers to these questions the interesting paradox emerges in that although 91 per cent. were in favour of smokeless estates and 87 per cent. thought it easier to keep house and clothes clean on these estates, yet 31 per cent. would return to using coal if they could.

Conclusions

These results represent tenants' thoughts after several years of compulsory use of smokeless fuels. The following main conclusions are suggested:

(*a*) There is little evidence of any change from the open fire as the principal means of warming the living room.

To some extent this attitude may stem from the tenant's reluctance to improve his landlord's property. However, in more recent smoke control areas we have noticed a growing tendency for owner-occupiers to install appliances better than the minimum necessary to burn smokeless fuel and in some cases to adopt gas for the main space heating load.

(*b*) Similarly, with water heating, the use of solid fuel with a back boiler or an independent boiler is practically universal. In homes with a high proportion of washing machines and television sets, it is surprising that the relative inconvenience of a fire is tolerated for supplying hot water in the summer months.

(*c*) Coke is generally accepted as the principal smokeless solid fuel. It should be emphasized that the districts surveyed are supplied with a consistent, high quality continuous vertical coke made from low ash Yorkshire coals and which for many years has been in general conformity with type "L" coke as defined in the British Standard Specification for Open Fire Coke (B.S.3142). Also, that the appliances which are giving this satisfactory service on coke are almost entirely the better type of approved open fires with $\frac{5}{8}''$ firebars which have been properly fixed and which are provided with integral gas ignition. In most cases long practice has helped users to acquire a satisfactory technique of coke burning.

In surveys carried out in smoke control areas of more recent origin the same high level of satisfaction with coke has not always been found and this is attributed to some combination of inexperience in use and of shortcomings in the appliance such as too narrow firebars, bad fixing, or lack of built-in gas ignition.

Acknowledgements

Thanks are recorded for assistance in the preparation of this Paper to the Medical Officer of Health and Chief Public Health Inspector of the City of Bradford and to colleagues in the North Eastern Gas Board.

THE MODIFICATION OF SIDE OVEN RANGES BY MEANS OF CONVERSION UNITS

By

*J. Baxendale**

Summary

In some Northern and Midland districts the cost of conversion of solid fuel side-oven ranges is a factor working against the introduction of Smoke Control Areas, as such conversions may cost up to £50. Conversion units have been developed which are satisfactory for installation on most types of solid fuel range. The unit is an orthodox solid smokeless fuel appliance minus the frame for holding the bottom grate. The installation and other details of the unit are described. As the conversion unit is not an approved appliance, discussions were held with Government Departments regarding grants under the Clean Air Act and it was finally agreed that the Minister would authorize grants on all installations provided that the installing contractor was prepared to give a certificate to the local authority concerned that the appliance would prove satisfactory in operation on the type of coke available in the area concerned. Before the granting of such a certificate a number of test installations have been made in proposed Smoke Control Areas. After a preliminary period of training and acclimatization a high level of consumer satisfaction has been recorded. The cost of such conversions is between £9 and £11.

Introduction

ONE of the main factors which concerns Local Authorities when considering their programmes for the implementation of the Clean Air Act is the cost involved. Due to the nature of existing appliances installed in property, such costs can militate against satisfactory progress being made.

In many parts of the North and the Midlands a particular problem arises due to the large number of houses, both Local Authority and private, in which old type solid fuel ranges are installed, and which, on first thoughts, would require complete replacement. Such replacement involves pulling out the existing range and the provision of a tiled fireplace and surround, together with an approved coke burning appliance. The matter is further complicated in that quite a number of the side ovens are still used for baking, necessitating the provision of an independent cooker. In cases of this type the cost per dwelling could well be of the order of £50. With these problems in mind the possibility was examined of converting solid fuel side oven ranges to coke firing yet still retaining facilities for cooking. After many experiments, in conjunction with a local firm of ironfounders, a conversion unit has been devised which has proved satisfactory for installation on most types of solid fuel range.

Design

To all intents and purposes this unit is an orthodox solid smokeless fuel appliance minus the frame for holding the bottom grate. Details of the component parts can readily be seen in photographs Nos. 1, 2, and 3.

Due to variations in range design, individual bottom grates are required for each make, and these are readily available, left or right handed to suit the location of the oven, and all grates have standard $\frac{5}{8}$ in. spacing between the bars. The units are fitted with integral gas ignition, which is highly desirable in order to promote easy lighting of the smokeless fuel.

Conversion units are supplied in different vitreous enamel finishes so that as close a colour match as possible can be made with the range to which

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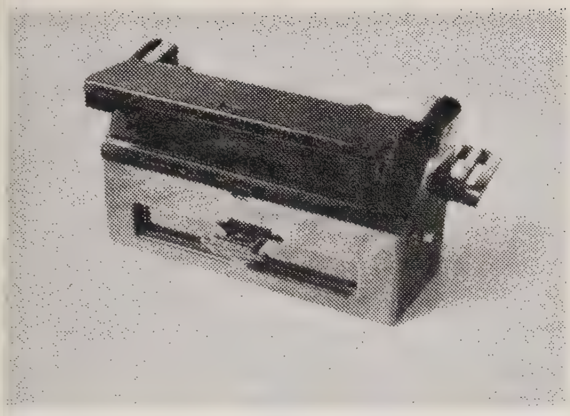
* General Manager, Bradford Group, North Eastern Gas Board.



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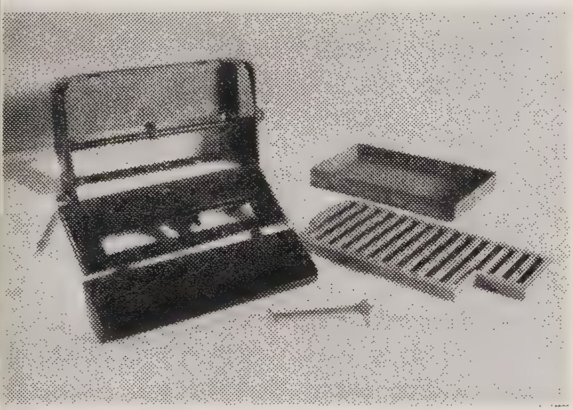

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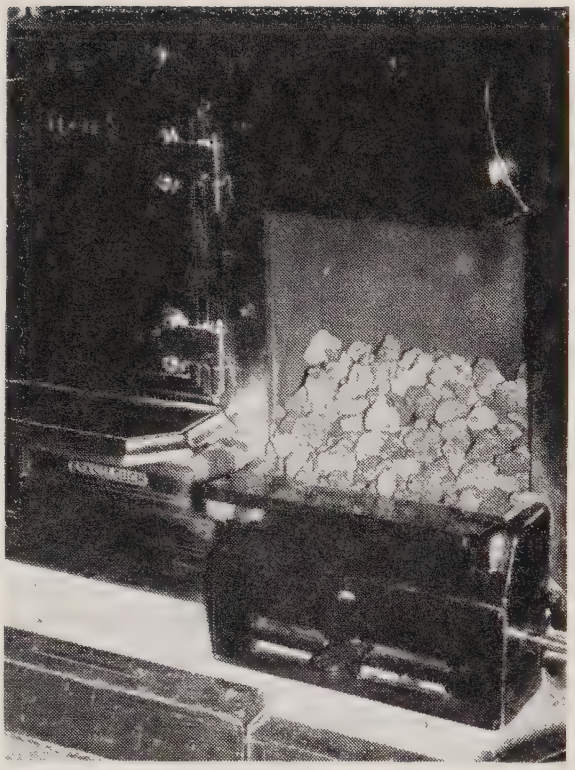

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the unit is to be attached. The conversion has proved suitable for the conversion of some 13 different makes of solid fuel range, although in certain instances minor modifications are required during manufacture to enable the unit to be firmly secured to the range frame.

As seen from illustration No. 4, the unit is quite pleasing in appearance, and the effective height of the fire bed varies very little from that of the original range.

A combined trivet and deepening bar is provided with the grate as a standard fitment.

Installation

The method of fixing is relatively simple and expeditious, and is as follows—the existing front bars, etc., of the range are removed and two holes are drilled and tapped in the front frame of the range. The conversion unit is then offered up to the front of the range and is firmly secured by two set screws. Sealing is effected by a proprietary brand of asbestos string impregnated with refractory putty. The gas supply is connected in the usual manner.

Operation

Technical assistance has been given to all users of conversion units, and, provided ordinary common sense is used, there should be very little difference in procedure to that applicable to ordinary smokeless fuel grates. Where baking is done in a side oven, a short period has to be allowed for acclimatization. Continuous vertical retort coke has proved satisfactory for use in all instances, and the recommended size is No. 2.

Qualification for Grant

Due to the fact that the conversion unit was not an approved appliance, discussions were held with the appropriate Government Departments regarding eligibility for grants under the Clean Air Act. The Departments concerned were impressed with the appliance and the extensive field tests carried out, and they appreciated the possibilities that the conversion unit offered to Local Authorities when implementing the provisions of the Clean Air Act at minimum cost and with the minimum of labour. It was finally agreed that the Minister would authorize grants on all installations provided that the installing contractor was prepared to give a certificate to the Local Authority concerned that the appliance would prove satisfactory in operation on the type of coke available for use in the area concerned. This responsibility was readily accepted, and such certificates have already been issued to some Local Authorities.

The normal procedure is for a number of test installations to be fixed in houses in the proposed Smoke Control Area, where it is known that the occupants will co-operate. After a reasonable period of tuition, the occupiers then operate the conversion units independently and in keeping with their normal domestic routine, which may include baking as well as the provision of hot water and space heating. After a reasonable interval of time, the householders are questioned thoroughly regarding performance, etc., and, based on the outcome, the necessary certificate is issued to the Local Authority.

It cannot be too strongly stressed that the modification will not remedy any inherent fault in an existing installation, and that certificates, when issued, can only apply to conversions that are carried out on existing ranges which have previously operated satisfactorily on coal.

Consumer Reaction

Whilst the implementation of the Clean Air Act is still in its early stages, several hundred units are now in satisfactory operation in the area of the Shipley Urban District Council and the Bradford Corporation, both in Local Authority and private dwellings, and many more are on order. It would be no exaggeration to say that in no instance has there ultimately been a desire to return to coal firing other than on the grounds of distinct prejudice. From time to time cases have arisen of unsatisfactory performance, but on investigation have been found to be due to individual practice of householders, for example, the use of hollow end bricks which has caused air tracking through the fire, inadequate depth of fuel bed, etc., but in every case the design of the fire has been exonerated and the difficulty cleared to the consumer's satisfaction.

Complaints too were received in the initial stages regarding the possibility of cold feet due to what appeared to be the increased height of the fuel bed. The fuel bed is, however, no higher than the orthodox grate, but the glow which previously showed below this level in the traditional range is absent in the conversion unit unless the primary air damper is open. In practice this fear does not materialize, and householders have been more than satisfied.

With regard to the provision of hot water: this is available more abundantly, and, until experience is gained, householders have had periodically to run off the hot water to avoid boiling. This is a good fault, as hot water on tap is always a boon to any busy housewife.

In special cases of low hot water usage the flue to the fire back can be appropriately restricted.

Householders report that baking conditions improve due to better constancy of temperature than when using coal. This improvement is probably due to the uniform depth of fuel bed which rarely applied with a coal fire.

A few householders in smokeless areas raised minor objections to the performance of the grate, but on analysis these were found to stem from an original conception that the Clean Air Act would enable them to obtain a new tiled fireplace, grate, and cooker with the greater part of the cost being defrayed by grant. Obviously grant can only be payable on necessary expenditure, and as a conversion unit will probably comply in all respects with the requirements of the Act, such persons have no valid argument.

Conclusion

Whilst there are undoubtedly other ways of converting combination ranges to the use of smokeless solid fuel, it is considered that the method outlined above provides an economical, simple, and expeditious solution, and it has been possible to provide and install units, complete with integral gas supply, for sums between £9 and £11, as against a possible expenditure of £50 which would be required to cover the cost of a replacement fireplace and means of cooking.

Conversion units are now being made by several manufacturers, and installation can be carried out either by the local Gas Board, private plumbers, or Direct Local Authority labour, but it must be emphasized that whoever accepts the responsibility for installing the grate must provide the necessary certificate of satisfactory performance to the standard and requirements called for by the Ministry before a grant is payable.

RECENT DEVELOPMENTS IN THE USE OF GAS FOR DOMESTIC HEATING

By

*G. H. Fuidge**

Summary

The use of gas for domestic heating has increased rapidly. This is due to demand for higher standards of heating and labour saving, but is also due to technical developments in gas appliances. Gas fire efficiencies of 75 per cent. are now attainable by sealing the combustion chamber. The demand for gas central heating by hot water has greatly increased, especially using the small bore system. Warmed air heating, either with direct gas-to-air heat exchange, or via a hot water boiler, is also being widely installed. The problem of venting the products of combustion in a high building has now been solved by the use of the branched or " shunt " flue. The problem of exhaust products is also made easier by the use of a sealed combustion chamber having inlets and outlets through an outside wall, terminated in such a way that the wind effects are " balanced " between inlet and outlet and do not affect the performance of the appliance, which is therefore known as a " balanced flue appliance." The installation of these balanced appliances in a tall building is also facilitated by the use of a " Se-duct," which consists of a simple common flue open at both ends.

Introduction

WHEN the Beaver Committee made recommendations on the reduction of smoke produced by the domestic chimney it looked to solid smokeless fuels to make the major contribution, with only a minor part to be played by gas and electricity. In actual fact, the use of gas for domestic heating has increased rapidly, as shown by the greatly increased sales of appliances. This is due in part to a demand for higher standards of heating and reduced labour arising from the increased standard of living and in part to the special domestic tariffs introduced by most Gas Boards; but perhaps the most important factor is the striking technical developments that have taken place in gas space heating appliances and related equipment. The purpose of this paper is to give a brief account of these technical developments.

Gas Fires

For many years past the most important space heating appliance has been the gas fire, and it will probably remain so for many years to come, for in providing radiant heat, it particularly meets the needs of the majority of British people. Until ten years or so ago the normal gas fire provided radiant heat only and consisted basically of a set of refractory radiants heated by the gas flames. The overall efficiency of these fires was of the order of 40 to 45 per cent.

The efficiency of the gas fire was improved by the incorporation of convection, at first by arranging passages for the room air to flow behind the back brick and return to the room through suitable passages above the radiants. Fires of this kind have efficiencies in the range 48 to 53 per cent. An important further step was the addition of heat-exchange chambers above the radiants for the extraction of further heat from the products of combustion. Fires incorporating this principle have efficiencies as high as 60 to 65 per cent. The two types of convector gas fire are shown in Figure 1. With these fires and gas supplied on one of the new domestic tariffs, the cost of heating by gas is of the same order or lower than the cost of heating by coal in the conventional stool bottom grate. A further reduction in the cost of heating together with improved standards of comfort have

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* Manager, Central Laboratories, South Eastern Gas Board.

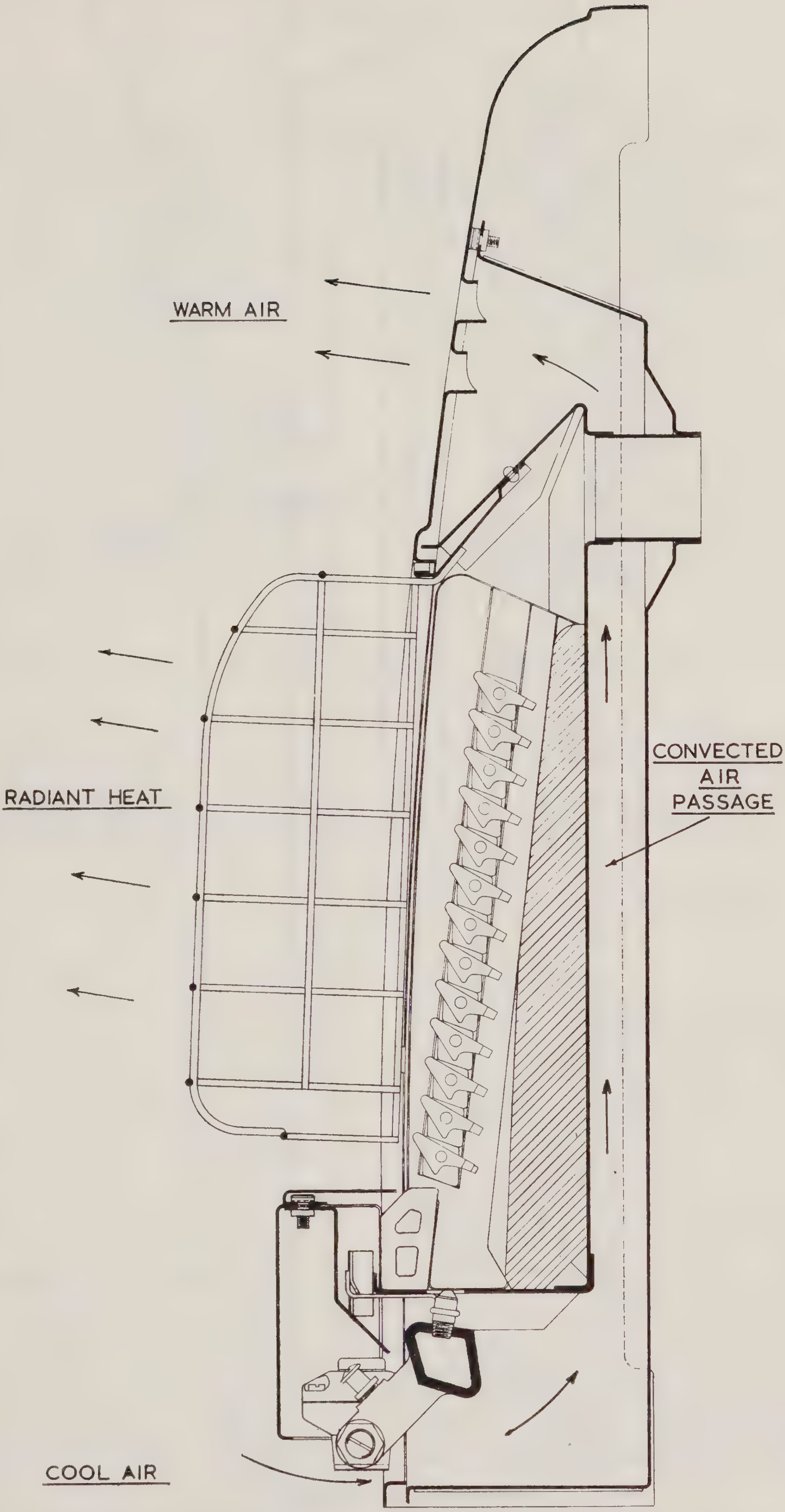


Fig. 1. (a) Simple Convector Fire (By courtesy of R. & A. Main, Ltd.)

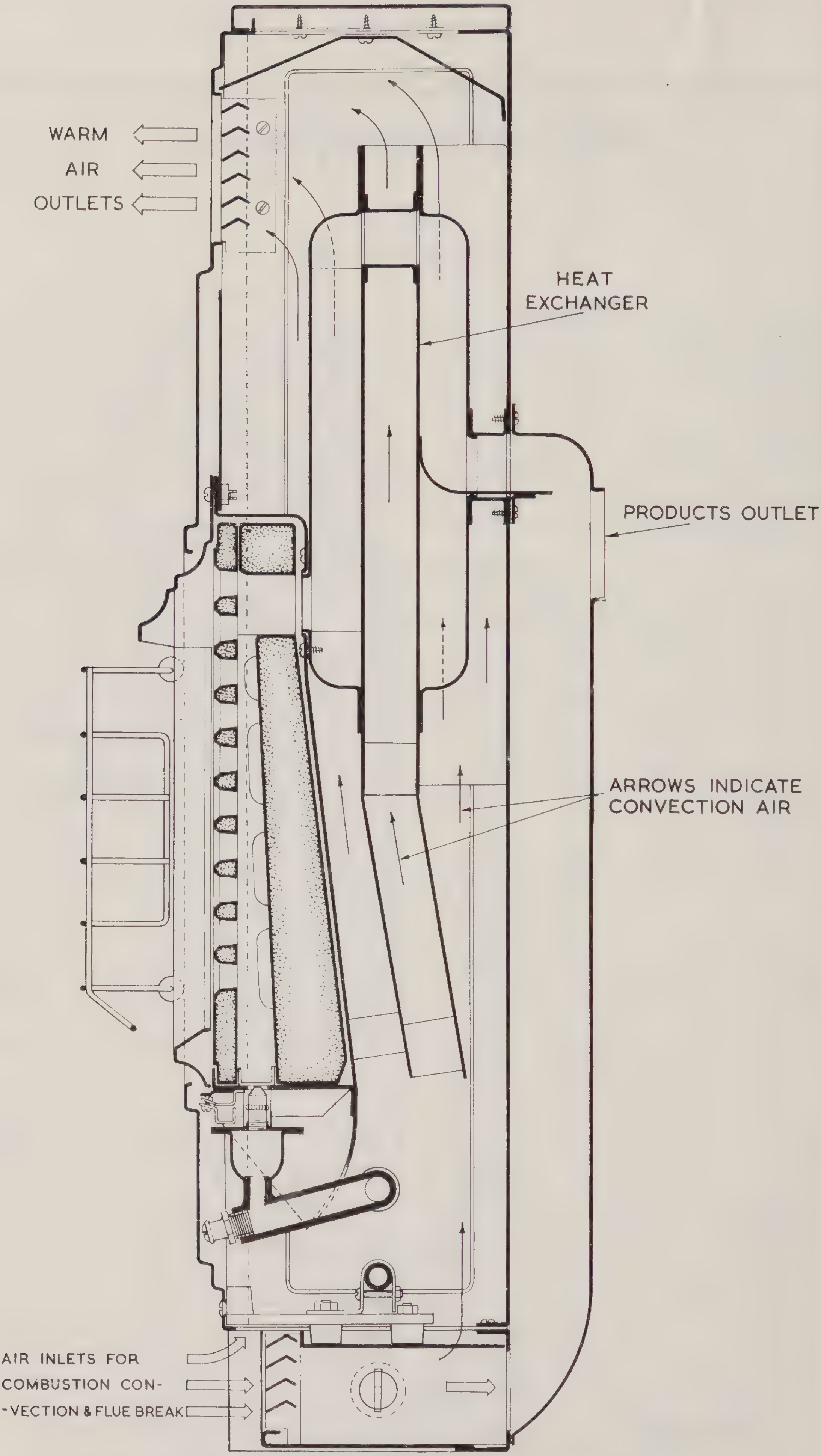


Fig. 1. (*b*) *Convector Gas Fire with Heat Exchanger* (*By courtesy of Bratt Colbran Ltd.*)

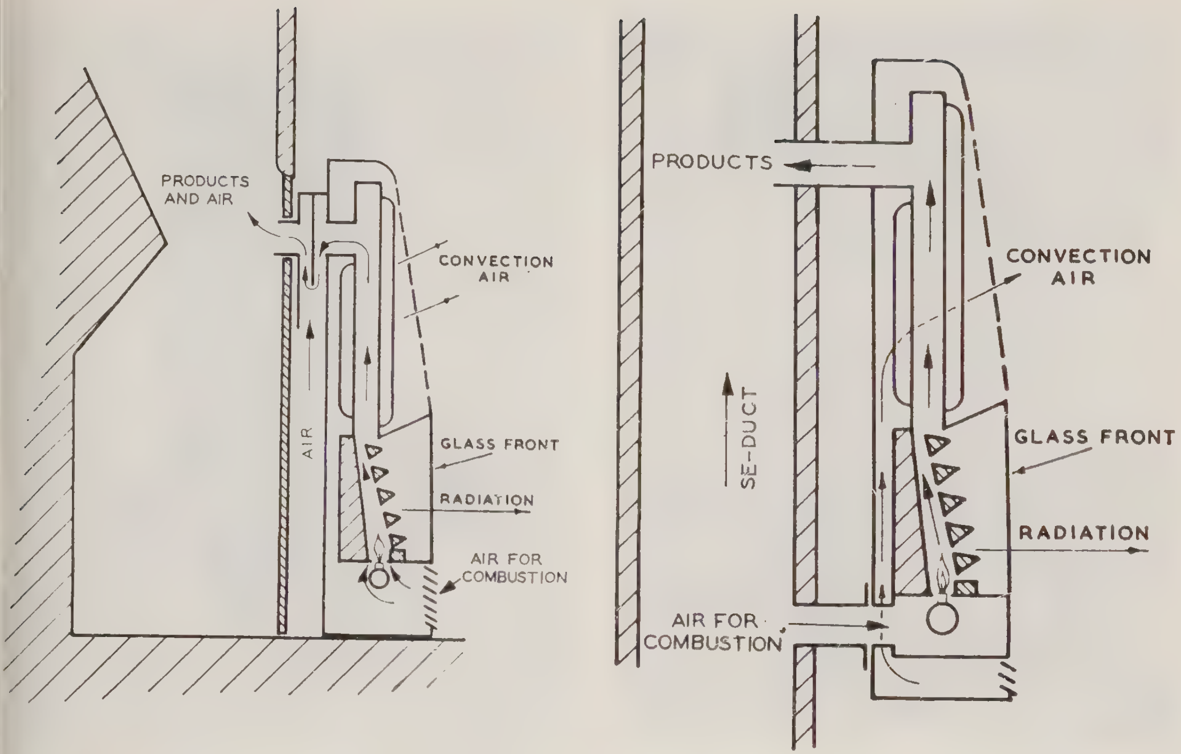


Fig. 2. Principle of construction of Gas Fire with closed combustion chamber. (L) As fitted to conventional fireplace (R) As fitted to a Se-Duct

been obtained by fitting a flue restrictor either into the chimney or into the flue spigot of the fire and so reducing the ventilation of the room from the excessive rate given by the ordinary chimney to a satisfactory rate of 2,000 to 3,000 cu. ft./hour.

The improvement in the efficiency of gas fires has not yet reached finality, and further improvements are in hand. Experimental fires are now on district trial in which the combustion chamber is enclosed by a glass fronted door. Apart from other advantages this sealing of the combustion chamber increases the heat transfer across the heat exchanger, so that efficiencies of the order of 75 per cent. are obtained.[1] The principle of the construction of a " sealed fire " is shown in Figure 2.

Central Heating by Hot Water

An example of the demand for increased standards of comfort is the rapid increase in the use of gas as the fuel for central heating, particularly in the smaller domestic installations, and sales of gas fired boilers have increased many-fold. The newer gas boilers are provided with fully automatic controls which make for safety and ease of ignition, and permit of thermostatic and time cycle control. An example is shown in Figure 3. The small bore pump assisted circulating system, developed by B.C.U.R.A. is becoming increasingly popular. The low capital cost of the gas installation is particularly advantageous for the small house.

Warmed Air Heating

Heating by the circulation of warmed air has been used as a method of central heating in America for many years. Full central heating or " whole house heating " by warmed air supplied from a " chimney furnace " fired by solid fuel, oil or gas, was developed in this country soon after the war. It is interesting to record that the proportion of new installations fired by gas has progressively increased from a small proportion at first to the majority at the present time. For reasons of cost the use of this system has tended to be restricted to the larger house and commercial premises. As with central heating by hot water, the gas requirement for a medium-sized house would be of the order of 700 to 1,000 therms per annum.

Another form of air heating has been

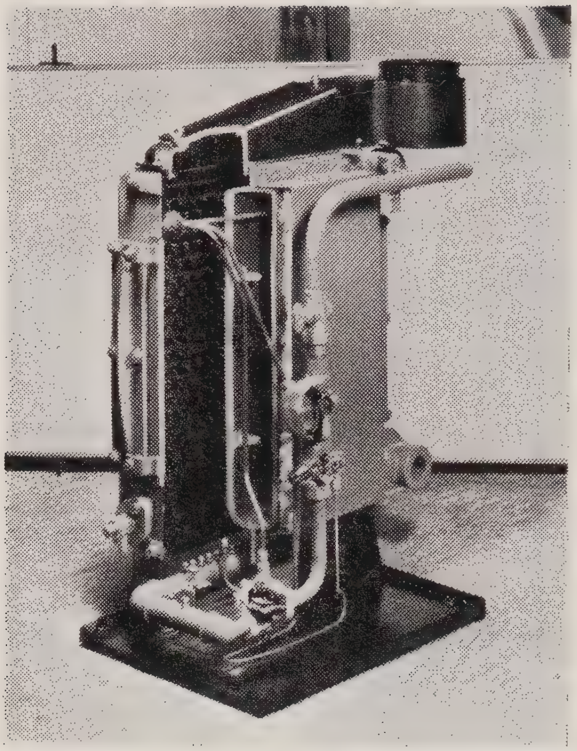


Fig. 3. Cut-away model of modern gas-fired boiler showing the controls (By courtesy of Thomas Potterton Ltd.)

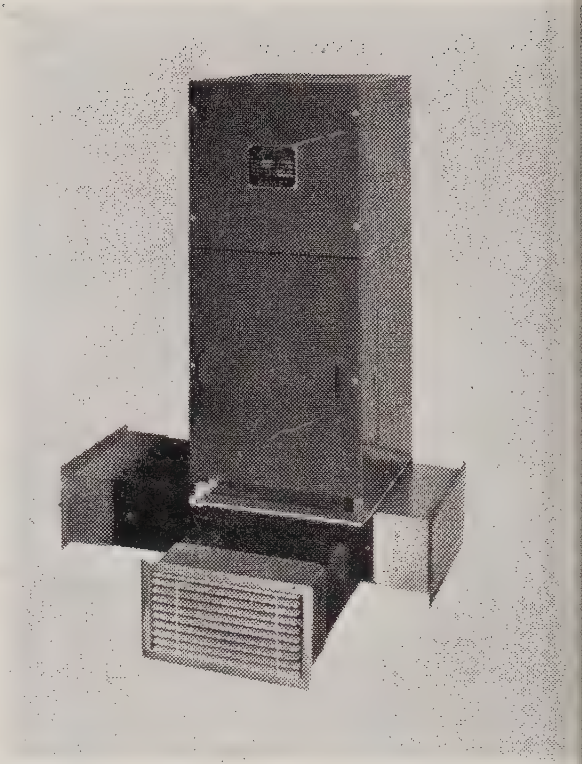


Fig. 4. Gas fired air heater with short ducts for selective heating (By courtesy of William Sugg & Co. Ltd.)

developed which is more suitable for the smaller house and flat. It is known as " selective heating " and the principle of the system is that the heater is of modest size with a heat output not necessarily sufficient fully to heat all the house simultaneously, but more than adequate to heat the main living space. The air heater is sited in a cupboard in such a position, as shown for example in Figure 4, that short ducts only are needed to reach the living room, other rooms, and the hallway or landing leading to the lesser-used rooms. It is a feature of the system that all the ducts are of the same cross section and each is capable of taking the full output of the appliance. Flap dampers in the ducts on the outlet grilles enable the air to be directed where required. By directing all the warmed air into the room to be occupied, very rapid heating up is achieved. It is usual for the installation to include a thermostat and clock control so that any heating cycle to meet the needs of the household can be arranged. Of course, a radiant fire can, if desired, be provided in the main living room.

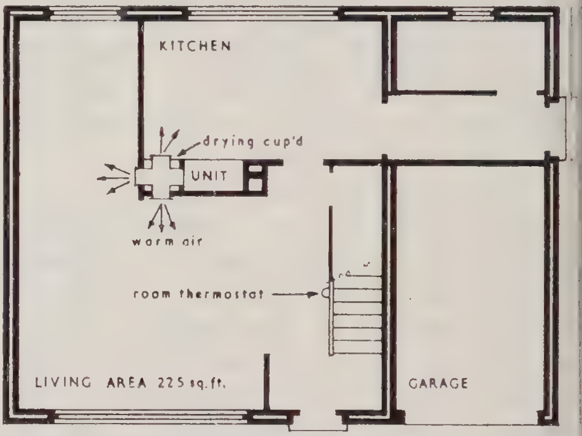


Fig. 5. Typical Layout of gas-fired air heating system in Open Plan Detached House (By courtesy of Radiation Ltd.)

With this selective system running costs can be remarkably low and gas consumptions of the order of 200 to 400 therms for a heating season are usual.

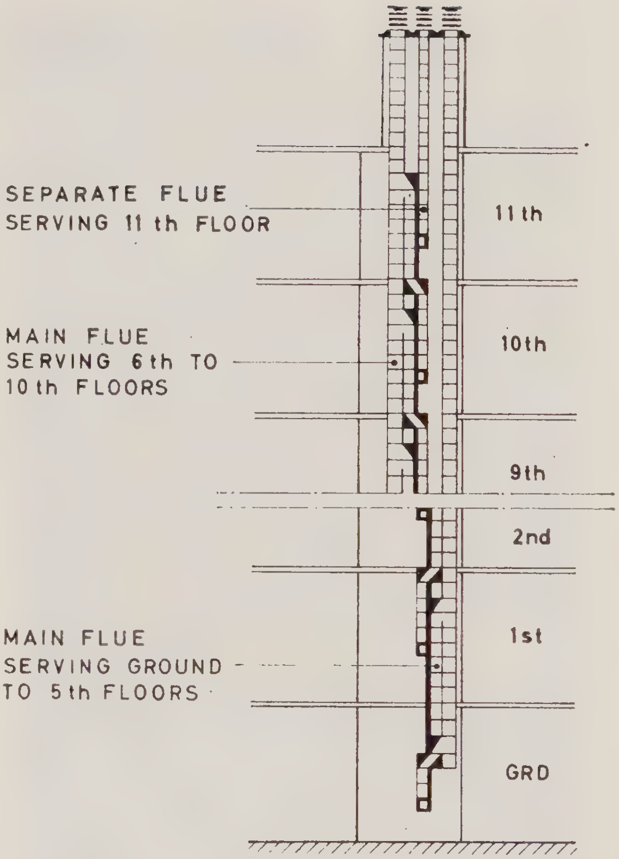
The appliance used is usually one with a direct gas-to-air heat exchanger and low speed fan; an example is shown in Figure 5. Alternatively the installation may consist of a hot water boiler and water-to-air heat exchanger. This has the advantage that a single appliance can be used to provide both space heating and hot water although the flexibility is less than with the direct air heater.

Disposal of Products of Combustion

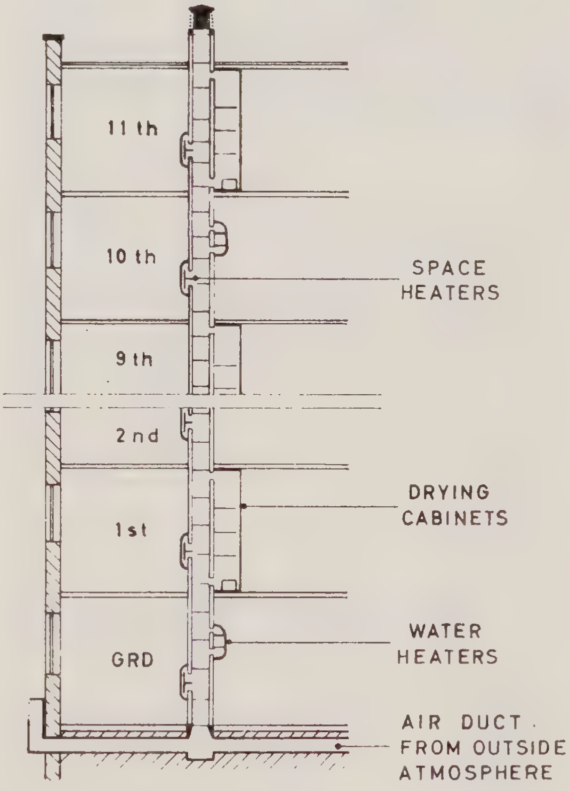
The development of gas for space heating, particularly in tall buildings, was until recently held back by the problem of venting the products of combustion. It was considered essential that each appliance should be provided with an individual flue; common flues, that is, flues to which more than one appliance is connected, were not normally permitted. Clearly, in a multi-storey block of flats a traditional flue system, especially if formed of the usual 9 in. by 9 in. brick chimneys, could be prohibitively costly and space wasting.

This position has now changed. A special form of common flue developed mainly on the Continent, known as the branched or " Shunt " flue, overcomes the main draw-back of the ordinary common flue system of possible intercirculation of products between different rooms. This is achieved by providing a length of primary flue between each appliance and the main flue by careful design of the whole flue system. " Shunt " flues are built from pre-cast blocks and are compact and space saving.[2] The principle is shown in Figure 6a. A number of installations of this system have been made in this country and they have been very successful, giving better performance than conventional flues. It is hoped that this type of flue will soon become generally accepted in building by-laws and regulations.

The problem of venting the products from a gas appliance is made easier by sealing the combustion chamber from the room. The sealed combustion chamber appliance can be fitted on to an outside wall and an air inlet and products outlet made through the wall, sometimes as concentric channels through the same hole, and terminated in such a way that the wind effects are " balanced " between inlet and outlet and do not affect the performance of


SEPARATE FLUE SERVING 11 th FLOOR
MAIN FLUE SERVING 6 th TO 10 th FLOORS
MAIN FLUE SERVING GROUND TO 5 th FLOORS
11 th
10 th
9 th
2nd
1st
GRD

(a) BRANCHED FLUE



(b) SE-DUCT

Fig. 6. Modern flues for Gas Appliances. Top: Branched flue system. Below: Se-Duct system

the appliance, which is therefore known as a " balanced flue appliance." This principle is being applied to an increasing extent and a considerable range of convector heaters, warmed air heaters and water heaters are available in balanced flue form.

The use of room-sealed combustion chamber appliances is greatly extended, particularly in tall buildings, by the " Se-Duct." This consists basically of a simple common duct extending vertically from the top to the bottom of the building, open at both ends and to which room-sealed appliances are connected. To balance wind effects at the base the vertical duct may be connected by two horizontal ducts to opposite sides of the building (Figure 6b). The appliances are so connected to the duct that they both take air from the duct and discharge products into it, for it has been found that correctly designed appliances will tolerate a considerable proportion of products in the air without any adverse effect on combustion or performance. The duct system is so designed in relation to the number of appliances and the height of the building that the maximum concentration of products entering the top appliance is well below the limit of tolerance.[3]

The Se-Duct has passed the experimental stage; a considerable number of installations up to 12 storeys high have been operating for some time and many more including 17 storeys are in the course of construction. Many types of appliances are available for fitting to the duct, including natural convector heaters, warmed air heaters, instantaneous and circulating water heaters, and clothes drying cabinets. It is hoped that shortly the sealed combustion chamber gas fire will also be available for fitting to the Se-Duct.

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[3] Observations on the Performance of a Multi-flue System and of a Single Duct for Appliances with Room-sealed Combustion Chambers. J. B. Carne, B.SC., T. T. White, B.SC., A.R.C.S. I.G.E. Communication No. 496.

DUST SAMPLING PROVIDES POLLUTION CONTROL

By

B. Lees, M.Sc., A.R.I.C., M.Inst.F., and M. C. Morley***

Summary

A sampler has been developed for routine assessment of the dust and grit emitted from boilers and other industrial plant. The sampler is extremely simple, yields consistent results and routine tests occupy only a few minutes per day. It is shown how the grit and dust burden from arrestors may be many times higher than " standard " if the plant is not tested regularly. It is recommended that all large dust arresting units and also some industrial boilers and industrial plant without arrestors should be fitted with a means of regularly measuring dust and grit emissions.

Introduction

THE Beaver Committee on Air Pollution 1954[1] stressed the importance of reducing grit and dust emission from the chimneys of industrial plant.

Mechanical arrestors and electrostatic precipitators have been fitted to many plants for this purpose. These are sometimes tested when originally fitted and it is then assumed that they continue to operate at their acceptance test efficiency; others are not tested but are assumed to operate at the designed efficiency.

Very few arresting plants are subjected to regular testing. This report describes a technique developed for this purpose. It also indicates that arrestors may operate unsatisfactorily due to a variety of causes which cannot be fully understood unless regularly tested.

The sampler was developed at Fulham Generating Station[2] for estimating the grit burden in the gas stream after multi-cyclone grit arrestors. Mechanical arrestors of this type will not retain fine dust (below one micron) and variations in efficiency of multi-cyclones are reflected in variations of the grit burden. It is the grit burden at the outlet of arrestors which affects local atmospheric pollution, the fine dust being blown away and widely dispersed.

Later the sampler proved to be equally suitable for measuring the solids burden in the flue gases at the outlet of electrostatic precipitators on pulverized fuel fired boilers.

The sampler consists of a hollow cylinder open at one end which is placed in the duct with the open end facing the gas stream (Figure 1). It is mounted on a rod for ease of handling and the method of insertion is illustrated in Figures 2, 3 and 4. The sampling position has to be where the gases are flowing horizontally or downwards.

The dust burden caught in the cylinder is measured daily. It has been found that the volume of dust and grit can be measured in a measuring cylinder instead of weighing it. In this way the estimation can be made by

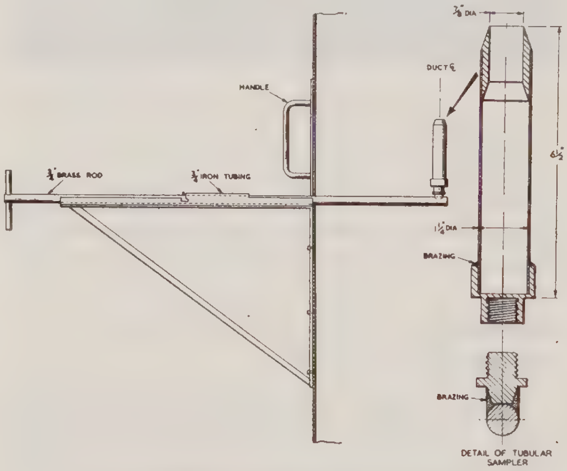

FIG. 1 DIAGRAM OF TUBULAR SAMPLER.

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* Industrial Fuel Technologist, British Petroleum Company Limited.

** Group Chemist, London Division, Central Electricity Generating Board.

Fig. 2. One of the early cylinders without a nozzle

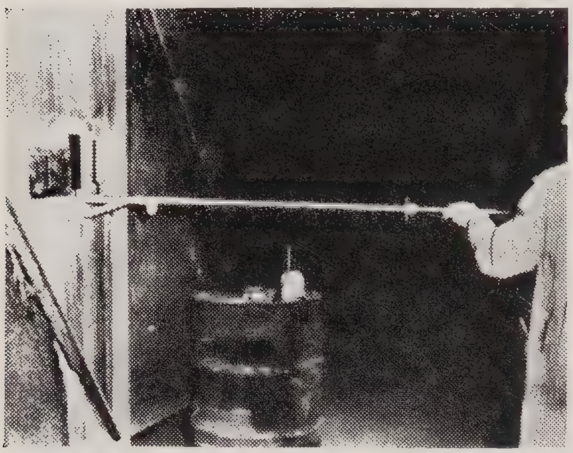

Fig. 3. Inserting the sampler in a vertical position

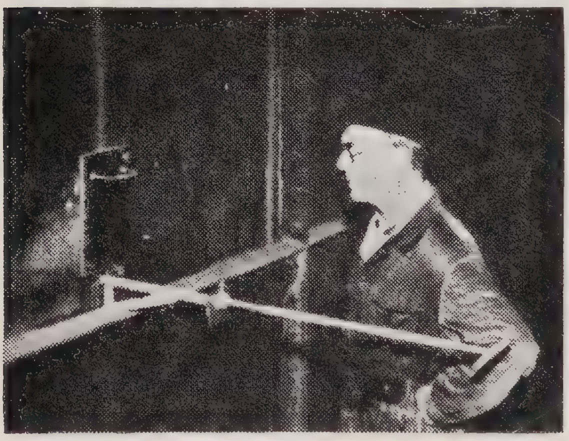

Fig. 4. The cylinder in position after being turned through 90° to face the gas stream

unskilled personnel, without using balances, an important factor when using the equipment for routine control.

Variation of the Dust Caught with Boiler Load

The Tubular Sampler is designed to make measurements over 24 hour periods, but as many plants do not operate at a constant load, it is necessary to correct for variation in loading conditions. On the three plants studied, it has been found that the quantity of dust caught at the outlet of the grit arrestors varies as the cube of the load. Based on this, the following formula enables day to day results to be compared despite variations in load.

The dust caught during 24 hours is multiplied by the factor

$$f = \frac{(\text{Maximum continuous rating})^3 \times N}{L_1^3 + L_2^3 + L_3^3 \quad .. \quad .. \quad .. \quad L_N^3}$$

Where N = number of regular load readings in 24 hours;
and L = load reading.

Multicyclones on Boilers Fired with Retort Stokers

The Tubular Sampler was designed for routine testing of multicyclones installed on stoker-fired boilers and the reliability and reproducibility trials of the instrument have been described in a previous paper[3].

The "standard" quantity of grit caught by the tubular sampler was first measured, that is with the boiler operating at its maximum continuous rating and the arrestor operating satisfactorily. This was found to be 500 mg./hr. Much higher results were obtained when some of the cyclones in the arrestor began to fail. There were no indications from pressure drop or other readings that the performance of the arrestors was deteriorating.

Multicyclones on Boilers Fired with Travelling Grates

Daily readings were taken of the grit burden at the outlet of multicyclones fitted on a boiler with a maximum continuous rating of 200,000 lb./hr.

The results of the trials are illustrated in Figure 5. The quantity of grit collected in the sampler, that is the "standard" quantity, averaged 48 mg. per hour during the first 20 days. After 24 days a high reading of 100 mg. per hour was recorded. The next day 185 mg. per hour was recorded confirming the deterioration. Examination

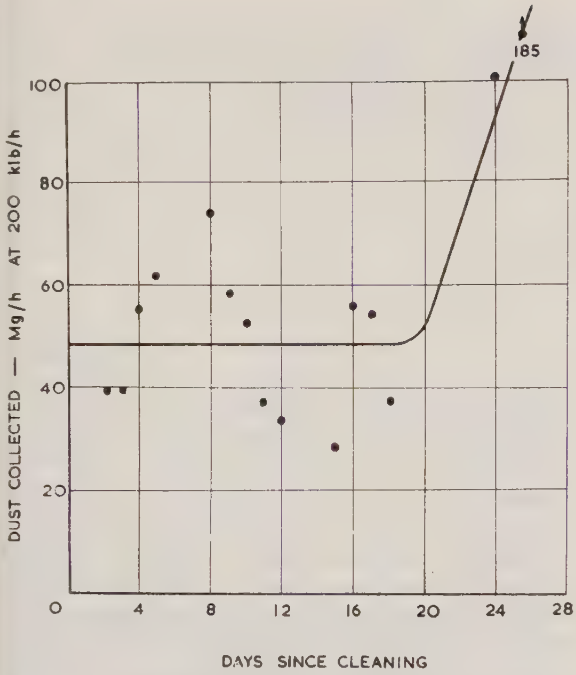

FIG. 5. DUST COLLECTED IN TUBULAR SAMPLER (CALCULATED TO 200,000 lb/h LOAD) ILLUSTRATING DECREASE IN EFFICIENCY OF MULTICYCLONES WITH TIME.

of the multicyclone showed that dust had blocked some of the outlet tubes. Pressure drop readings gave no indication that this deterioration was taking place.

Regular readings were then taken for several months, Figure 6. The following is a summary of observations made during this period:

January 2nd: Trial began with a clean arrestor. " Standard " quantity of grit collected in sampler until February 9th.

February 10th: Arrestor began to fail.

February 20th: Arrestor should have been cleaned. There were no other indications (i.e. pressure drop) that the arrestor required cleaning. Outlet grit burden now four times higher than " standard."

March 23rd: Plant cleaned. In the period during March before the arrestor was cleaned the outlet grit burden was 20 times higher than standard. After cleaning, the plant operated satisfactorily during April. Quantity of grit caught in the sample was " standard."

May 7th: Arrestor began to fail.

May 16th: Arrestor given a quick clean. Sampler indicated that this was not adequate.

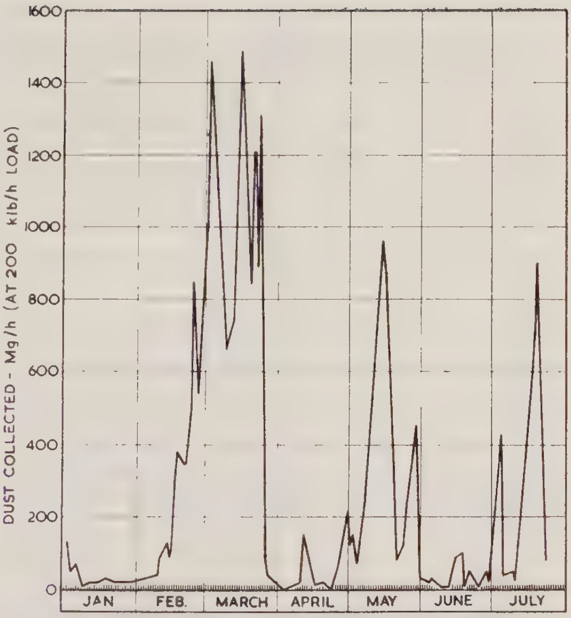

FIG. 6 DUST COLLECTED IN TUBULAR SAMPLER (CALCULATED TO 200,000 lb/h LOAD) AT OUTLET OF MULTICYCLONES. BOILER WITH TRAVELLING GRATE.

May 31st: Arrestor cleaned thoroughly. Grit caught returned to " standard."

It was concluded that the plant required cleaning once every five weeks. If it was not cleaned the grit emission could become 20 times higher than standard.

Electrostatic Precipitators on a Boiler Fired with Pulverized Fuel

The tubular sampler was used for assessing the solid burden in the flue gases at the outlet of an electrostatic precipitator fitted on a boiler fired with pulverized fuel. Details of calibration trials are included in the previous paper[3]. Trials were carried out over a period of one year on a boiler of 400,000 lb./hr. capacity. The quantity of solids as collected by the sampler was measured by volume in a measuring cylinder and expressed in lb./hr. burden in the total gases from the precipitator.

The results are plotted in Figure 7. The " standard " quantity caught in the sampler was 10 lb./hr. The dust burden in March, June and November was nearly down to this standard. Results in February, April and October were moderately satisfactory, with the solid burden about twice the " standard." During July, just before the annual overhaul, the boiler plant operated badly and the dust burden at

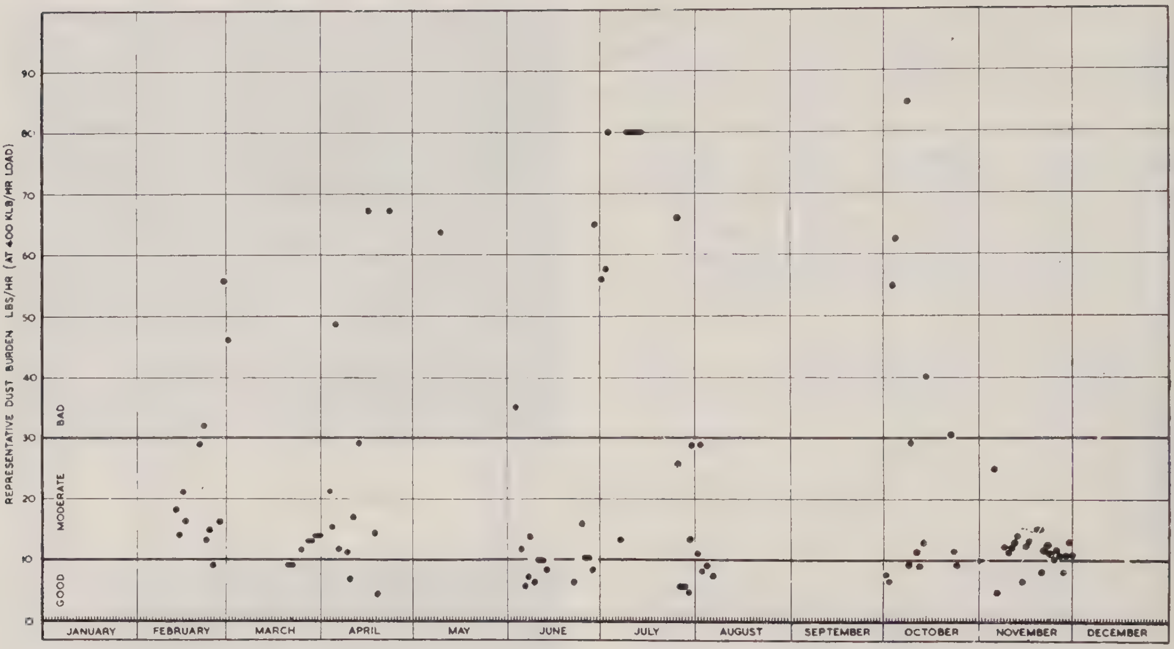

FIG. 7 REPRESENTATIVE DUST BURDEN COLLECTED BY TUBULAR SAMPLER AFTER PRECIPITATOR. BOILER WITH P. F. FIRING

the outlet from the precipitators was five times higher than the "standard."

Conclusions

The tubular sampler is simple, reliable and requires very little attention. It can be operated by unskilled personnel.

With mechanical arrestors it will indicate:

(*a*) The optimum period an arrestor may be operated before it should be cleaned.

(*b*) Whether cleaning has been done properly.

(*c*) Whether there is a mechanical fault in the operation of the arrestor, such as defective hopper valves.

(*d*) The effect of fuel and boiler or plant operating conditions on the emission of grit in the flue gases.

With electrostatic precipitators it will help to indicate:

(*a*) The optimum electrical power input required for high availability and low emission of solids in the flue gases.

(*b*) When the electrodes are damaged.

(*c*) When precipitators have been allowed to remain tripped out for too long a period.

(*d*) When hoppers have been allowed to become too full.

(*e*) When boiler operating conditions result in a high percentage of combustibles in the ash.

Recommendations

All plant fitted with grit and dust arrestors should be fitted with equipment for measuring regularly the dust burden at the outlet from the arrestor.

The results recorded indicate how the dust and grit passing into the atmosphere from these plants may be many times higher than "standard."

The trials described were carried out on industrial boilers. It is equally as important that the dust burden should be determined at the outlet from other industrial plants such as furnaces and cement kilns. In many cases measurements could also be made profitably on the flue gases from plant without arrestors to assure that they are operating satisfactorily and are emitting only a low quantity of dust and grit.

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[3] A Routine Sampler for Detecting Variations in the Emission of Dust and Grit. B. Lees, M.SC., A.R.I.C., M.INST.F, and M. C. Morley. Journal of The Institute of Fuel, February, 1960.

PREVENTION OF SMUTS WITH OIL-FIRED BOILERS AT LOW-LOADS

By

*F. Squirrell**

Summary

Low load conditions may give rise to smoke and smut emissions from oil-fired boilers. This is consequent upon the inherent efficiency of an oil-fired boiler and the resulting low temperature of the flue gases. It is suggested that this problem can be overcome by running the burners with restricted turn down, and using the boiler as a thermal storage unit. This can be done by means of gas tight-sealing units at the boiler outlet which close as soon as the burners cut out, and open again just before the burners cut in. The heat is thus sealed in and the burners operate at their most effective rate.

THE extension of the Clean Air Act may decisively weigh the scales in favour of oil-firing, particularly where boilers operate near residential areas. Although a coal-fired boiler may be cheaper to install and run, cleanliness, the saving of space and of labour, are important considerations. The prevention of smuts and smoke, however, is often the deciding factor.

It is a common experience, however, that low-loads with oil-fired boilers are often accompanied by smut emission and often with smoke and low-temperature corrosion as well. The smuts, of course, may not appear during the actual period of low-load running. They will accumulate within the stack during this time, to be discharged when the steam demand increases and gas flow follows suit.

These problems of smut emission and the corrosion of metal ducts or boiler surfaces have frequently been regarded as faults of the burner system. Many attempts have been made to improve or re-design the oil burners, without great success.

The faults, however, do not lie in the burners at all; in fact, the " faults " do not lie anywhere.

1. Modern Economic boilers operate with low exit temperatures (a criterion of high efficiency).
2. These exit temperatures are already low when the rate of burning is at its highest, i.e., at full heat input.
3. Reduce the heat input and the temperatures will fall still further—in many cases to the point at which smoke, smuts and corrosion are produced.

And these circumstances are inherent by virtue of the very efficiency of the boiler design.

Gradually, these problems are becoming recognised. One suggested remedy is to insulate or sheath the chimney stack. This only applies, of course, to metal stacks. It is only effective in maintaining the temperature of the gases within the stack itself. If the exit temperatures of the boiler are low and continue to fall on their way to the stack, (e.g., through stand-by boilers) sheathing is no solution. It cannot raise an already low temperature.

Another method is to design individual stacks for each boiler or to divide an existing stack into separate ducts. This is a costly business.

Both these methods seek to maintain gas temperatures which have already fallen sharply, due to a restricted heat input.

Why not maintain the heat input itself at a high rate?

The obvious way to keep up the exit temperatures is to restrict the turning-down of the burners. This will also

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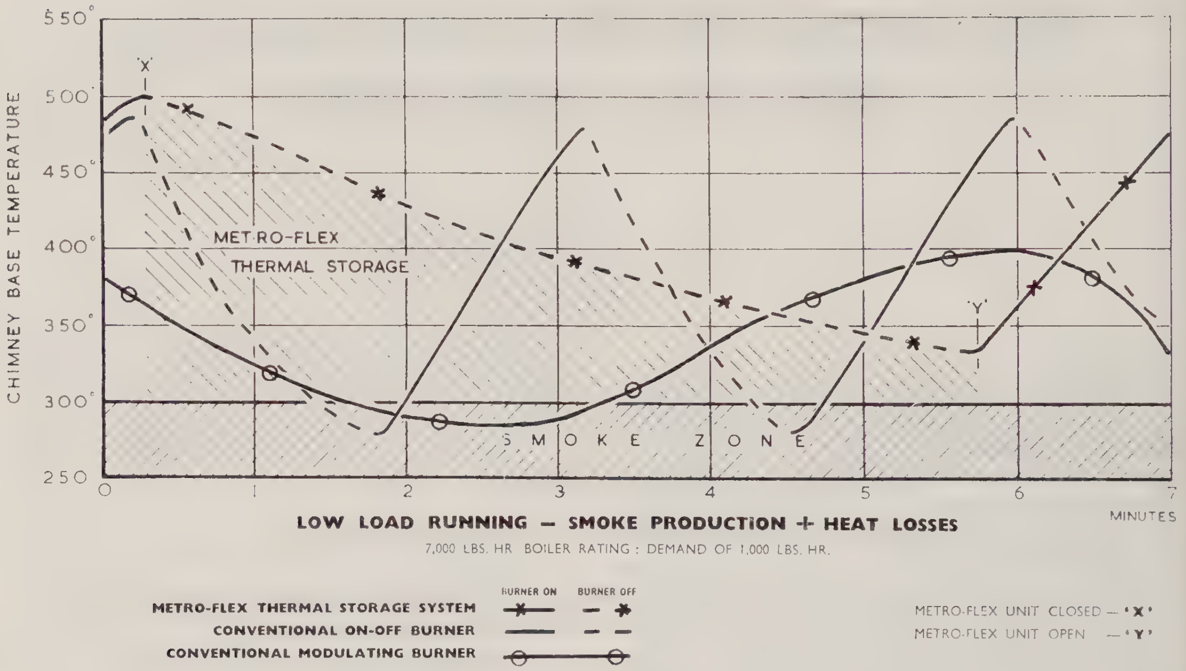

LOW LOAD RUNNING — SMOKE PRODUCTION + HEAT LOSSES

7,000 LBS. HR. BOILER RATING : DEMAND OF 1,000 LBS. HR.

mean that firing will proceed at its most effective rate at optimum efficiency. But it also follows, of course, that during low-load running the burners will cut out frequently. At those times, the exit temperatures would normally fall still more rapidly. The only effective answer will be apparent: the boiler itself should be used as a thermal storage unit during these cut-out periods.

A complete thermal storage oil-firing system has now been developed. The oil burners of any existing boiler can be used. The turn-down ratio of the burners is deliberately restricted, after which they cut out. At once, a gas-tight sealing unit, fitted at the boiler outlet, begins to close. The boiler is isolated completely, with all the heat "sealed in." The lower steam demand is drawn from the boiler, used as a thermal storage unit. Avoidable heat losses are absolutely nil.

When next the pressure-stat operates, the gas-tight sealing units open and the burners cut in, operating throughout at an effective rate.

Exit temperatures are thus kept well up above trouble point. When firing proceeds, excess air is properly restricted, (most effective at a high burning rate); whenever the burners cut out, the boiler is "sealed off" and no air whatever passes to chill the hot working surfaces.

The problem is tackled at its source —the heat input is raised. The burners are operated only at their effective rate and the boiler itself is used as a heat accumulator.

Apart from the prevention of smuts, smoke and corrosion, there would be a considerable bonus in the form of fuel savings. The Thermal Storage System, is by far the most effective method of meeting low-loads.

Further particulars of the Metro-Flex Thermal Storage System can be obtained from The Metropolitan Engineering Co., Ltd., 47 Whitechapel High Street, London E.1.

NATIONAL COAL BOARD TECHNICAL SERVICE AND THE CLEAN AIR ACT

By

A. Harrison Slade, B.Sc.Tech., F.Inst.F.[*]

Summary

The N.C.B. Technical Service arose largely to meet the competition of and the needs of consumers for assistance in meeting the Clean Air Act. Its scope is to provide up-to-date information about coal-burning equipment, the availability of suitable qualities of coal and the opportunities for using it without infringing the Act. The country is divided into nine sales regions in which are both commercial and technical representatives. The Service's work in connection with Section 1 of the Act deals with many of the causes of emission and thus assists the Smoke Inspectors, who are left free to deal with more wilful offenders. The Service is assisting local authorities and industrialists with advice concerning temporary exemptions under Section 1 and permanent exemptions under Section 11 of the Act. The technical staff of the service is assisting consumers to avoid making a nuisance by emitting grit and dust. For pulverized fuel firing it is felt that there is a pressing need for a dust extractor considerably cheaper than the electrostatic precipitator. The Technical Service has been greatly encouraged by its reception and intends to improve as far as practicable.

THIS service, which is available free of charge to all industrial and semi-domestic consumers, was considerably augmented last winter and is continually being expanded to meet the growing demands on it which have arisen mainly through two factors:

1. The need to counter the intense competition from oil.
2. The needs of consumers for assistance in meeting the requirements of the Clean Air Act.

The Government has given official recognition to the N.C.B. Technical Service in that the Minister of Housing and Local Government has circulated to local authorites the copy letter to it from the Minister of Power wherein he calls attention to the N.C.B. Service and its purposes which, to quote his own words, " are to provide up-to-date information about coal burning equipment, the availability of suitable qualities of coal and the opportunities for using it without infringement of the Clean Air Act."

The Minister's words put tersely the scope of the work which covers the very wide field of combustion engineering, all of which can be said to have some bearing, however indirectly, on the Act, whether it is advisory service or practical service in assessing plant efficiency, demonstrating skilled firing, etc.

Organization of the Service

The country is divided into nine Sales Regions each having its own team of representatives directed by the Regional Sales Manager. These have their headquarters in the following towns:

London, Newcastle (both Durham and Northern Regions), Mansfield Woodhouse, Dudley, Edinburgh, Manchester, Cardiff, Sheffield; Branch Offices in Swansea, Leeds, Bristol, Prestwick, Glasgow, Cowdenbeath, etc.

There are both Commercial and Technical Representatives, the former being conversant in all the commercial aspects governing supplies and having an intimate knowledge of the coals sold in their Region. Their routine calls on consumers, local authorities, etc., enable them to act as the eyes and ears for the technical representatives who can plan their preliminary action accordingly.

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[*] Chief Fuel Technologist, Marketing Department, National Coal Board Headquarters.

All the technical representatives are either professionally qualified fuel technologists or practical stoker demonstrators by virtue of many years experience on the firing floor operating and maintaining plant to get best efficiency out of it.

Some idea of the contacts made with consumers, Public Health Officers and plant manufacturers may be gleaned by the fact that the various types of representatives have between them this year (to June) made some thousands of visits.

The appraisal of our service work in furtherance of the Act cannot be assessed however merely in quantitative terms of visits carried out but must be judged qualitatively. In this respect there are many signs that its work is welcomed and appreciated, not least from numerous Public Health Officers who have been unstinted in their appreciation of the help and relief it has afforded them.

Service Work Specifically Related to the Clean Air Act

Some insight into the work of the Service can be conveyed in reference to the main Sections and purposes of the Act as follows:

Section 1. *Prohibition of Dark Smoke Emission*

In addition to the causes of smoke which are allowable by the Act as defences, we find that much of the trouble stems from bad operational habits or prejudices which are overcome by technically and tactfully competent personal approaches to Management or operators.

Other causes of smoke, such as unsuitable fuel, overloading, lack of instruments, and poor plant maintenance can, in general, soon be established and a solution laid on.

This work obviates many prosecutions and relieves the smoke inspectors who can be left to deal with any recalcitrant or wilful offenders.

Section 2. *Temporary Exemptions from Section* 1

As the time limit for exemption, i.e. July 4th, 1963, gets nearer one can expect the number of exemptions granted to dwindle. As exemption is not a temporary licence to go on making smoke due to faulty operations, plant or fuel, our service staff has been active in advising consumers regarding conversion from hand to mechanical firing and assisting *pro tem* with recommendations and instruction on hand firing. In view of the thousands of plants still hand fired there is a tremendous amount of work to be tackled in this field, as our preliminary surveys have indicated.

Section 11. *Smoke Control Areas*

Until the Minister exercised his powers under Section 11 (4) the coal industry was labouring under a great handicap and inevitably lost much ground to oil firing, which it is now steadily recovering since the Minister's " blanket " exemption was given for mechanical stokers installed after December 31st, 1956. This exemption put coal and oil firing in the same position as regards smoke emission so that neither could claim any advantages over the other. Much misconception, contention and occasional discrimination against coal firing is being encountered, which our technical staff are actively engaged in dispelling, not without considerable success.

On the one hand there are local authorities freely recognizing the Minister's order to allow fuels other than authorized fuels to be used without producing smoke or a substantial quantity of smoke, while there are others intolerant of the latter qualification, which one grants must achieve a degree of smoke emission tighter than Section 1 allows.

Where smoke control areas are proposed, our service staff maintain close liaison with Public Health Officers, who have been most co-operative in checking over with our staff:

1. The consumers having mechanically fired plant installed before January 1st, 1957, which the Public Health Officer considers will not qualify for exemption unless improved in operation.

2. Consumers hand-firing bituminous coal requiring plant conversion.

Selection of suitable fuel, demonstration of correct firing or plant modification to bring it up to date with latest practice invariably effect a cure.

Public Health Officers have welcomed the many visits arranged by our service men for them to see typical plants which are readily complying with the Act. In particular, much effective work has been done in demonstrating that underfeed stokers comply with Smoke Control Area requirements when correctly fitted with over-fire air jets or modulating air and fuel controls.

Section 5. *Grit and Dust from Furnaces*

While the Clean Air Act can be said to deal in general very effectively with smoke emission, this cannot yet be claimed for grit and dust.

The Act does not define grit and dust or what are acceptable levels of discharge nor does it require apparatus to be used to determine the emission of grit and dust or records to be kept of same. These omissions are understandable and widely held to be wise in view of the complexity of the problem, the lack of authentic data available as to the exact nature of emission and how these are related to various factors governing the size and amount of grit emitted and its dispersal. As regards grit sampling apparatus, much work has been done by the Central Engineering Establishment of the National Coal Board and the British Coal Utilization Research Association in developing apparatus which makes the sampling of grit as easy, cheap and reliable as industrial plant operations demand. Until such an apparatus is standardized and officially approved and the Act can be made much more specific, our technical staff is doing much for consumers that is expedient to avoid grit and dust being a nuisance to the consumers themselves or neighbours, on existing plant without installing a grit arrestor, which we find in general unnecessary except on a pulverized fuel fired plant.

Our work in this field has shown that in the vast majority of existing boiler plants solid emission of any nuisance value can be obviated and the intention of the Act observed providing the interpretation of the words " practicable " and " practicable means " in Section 5 (i) of the Act, which says of existing furnaces " consumers shall use all practicable means of minimizing the emission of grit and dust " is that given in Section 34 (1) of the Act and not as inflexible as if the Act had demanded virtual elimination regardless.

As regards pulverized fuel firing in particular on new furnaces (for which grit arresting plant is obligatory regardless of method of firing) and bearing in mind that the Minister's exemption excludes P.F. furnaces, we feel there is a pressing need for dust extraction plant, whether of the electrostatic or other type, considerably cheaper in capital cost than the electrostatic ones available today and efficient enough to enable the inherent advantages of pulverized fuel to be more widely enjoyed by general industry instead of it languishing as is the case today.

The Technical Sales Service of the National Coal Board although instituted on any sizeable scale so recently has been generally encouraged in its work by the way it has been welcomed by consumers, Public Health Officers, plant manufacturers and all bodies concerned with the efficient use of fuel and the implementation of the Clean Air Act. The Service will not stand still as the demands on it are growing apace and can only be met by continuing to improve and expand the Service as far as practicable.

MEASUREMENT OF DUST EMISSION FROM STEELMAKING FURNACES

By

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*A. E. Pengelly, B.Sc., A.Inst.P., and F. A. Gray, F.Inst.F., A.I.M.**

Summary

New processes of iron and steelmaking have created new dust emission problems. The monitoring of these emissions is necessary for the design of fine fume cleaners and the paper describes work carried out by United Steel Companies. Concentrations of dust have been estimated by means of optical density measurements, using a smoke density meter, and the results are presented graphically on what is called an obscurogram.

Introduction

DUE to improved efficiency and in particular to improved fuel economy, air pollution due to the combustion of fuel in the iron and steel industry, is a comparatively minor problem today.

New processes of iron and steelmaking have, however, created new problems. These arise principally from the use of oxygen, for example, in the desiliconizing of pig iron, in oxygen blown steelmaking processes—such as open hearth and electric arc, and for the deseaming of ingots. These processes yield large volumes of fine fume or dust, mainly iron oxide, which, because of its sub-micron size, is far more difficult to deal with than smoke from the combustion of fuel.

Depending on the concentration, the effluent velocity and local atmospheric conditions, this fume emerges from plant stacks as a brown or deep red plume. The obscuration of light by a cloud of fine fume is much greater than that for a similar mass of coarse dust, and this frequently gives an exaggerated impression of the mass of effluent material. The appearance of the chimney plume and the weight of dust discharged are not directly related. The finer the dust for a given concentration, the denser is the appearance of the plume, because the equivalent surface presented to light transmission is much greater. Table 1, below, shows the equivalent projected area when a one cm. radius sphere is sub-divided into spherical particles of decreasing radius.

TABLE 1

Effect of Particle Sub-Division on Total Projected Area.

Particle Radius — cm	*Total Projected Area—cm²*	*Number of Particles*
1·0	π	1
0·1	10π	10^3
0·01	$10^2\pi$	10^6
0·001	$10^3\pi$	10^9
0·0001	$10^4\pi$	10^{12}
0·00001	$10^5\pi$	10^{15}

Steelmaking processes, particularly converters, have been the cause of fume since their invention, but only in recent years has the problem been of serious concern. Increased total steel production in new plant and by harder driving of open hearth furnaces, mainly using oxygen, has caused the rapid increase in fume emission. Iron oxide fume is not toxic and therefore not a menace to general health. When properly dispersed from high stacks there is no appreciable loss of sunlight, but the local visual nuisance is considerable and eventual deposition, even though widely dispersed, is undesirable.

To eliminate the visual effect and

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* The United Steel Companies Limited.

achieve a " clean " stack means that the effluent concentration must be reduced to about 0·05 grains/ft.³—a degree of cleanliness which it is only possible to achieve with a few types of highly efficient separators.

Without exception these fine fume cleaners are very expensive and it is therefore imperative that the best equipment be chosen for any given plant. In order to determine design factors for installations, it is necessary to measure the existing dust emission, gas volume flow and temperature, and to know the properties—particularly the mean size, of the dust produced.

It is with measurement and monitoring of dust concentration and total emission that this paper is concerned.

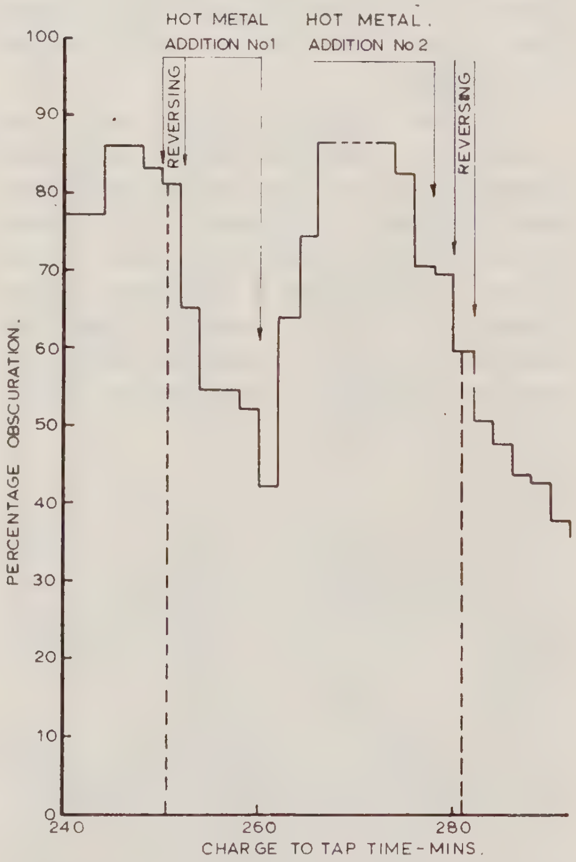
Measurement of Dust Emission

The Clean Air Act defines dark smoke by its appearance at the chimney, but it does not define tolerable weight emission levels. For plant design, however, concentration, loading and size range are the main design factors and these may well be very different for a given optical appearance, particularly in the case of the main iron and steel pollutant, iron oxide of various size distributions.

The standard method of determining concentration of suspended matter in gas is to pass a measured volume of the gas through a filter, the deposit in which is weighed. This is the basic method used by the United Steel Companies; the techniques and equipment have been developed from standard practices used elsewhere.[1,2] Unfortunately this gravi-metric method is a batch process and cannot give a continuous record. Furthermore, the technique is not simple, takes an appreciable time, and cannot therefore be used for routine measurement. It is desirable then, that a method be found, suitable for continuous everyday use.

In boiler-house practice the problem has been solved with the use of commercial instruments which measure the optical density of the flue gases.[3] It was shown by the Fuel Research Station that for certain boilers the optical density of the flue gases can be related to the concentration of suspended matter. The same relationship cannot be expected to apply to steelmaking furnaces because of the difference in mean particle size of the solid material. If a similar relationship could be established, however, it would provide a simple working method for indicating and recording of fume and fine dust loadings in the waste gas from steel plant.

A number of experiments has been carried out by the United Steel Companies Research & Development Department to measure the dust emission and optical density of flue gases from open hearth and electric arc furnaces. It has been shown that a relationship between the two parameters exists. The first experiments were made on a large tilting open hearth furnace



OBSCURAGRAM FOR OPEN HEARTH FURNACE DURING HOT METAL ADDITION

FIG. 1

working with normal hot metal practice and without oxygen injection in the bath. The sampling site was 50-feet up the 170-feet stack, which was provided with a sampling point built to British Standards Specification No. 893. All solids passing the sampling section emerged to the atmosphere.

The first phase consisted of monitoring, with a smoke density meter, changes in emission level with different operations and stages in the open hearth process. These results were presented on what is now called an obscuragram. This presents the variation of percentage obscuration in relation to time and melt phase, and a section of a typical diagram is shown in Figure 1.

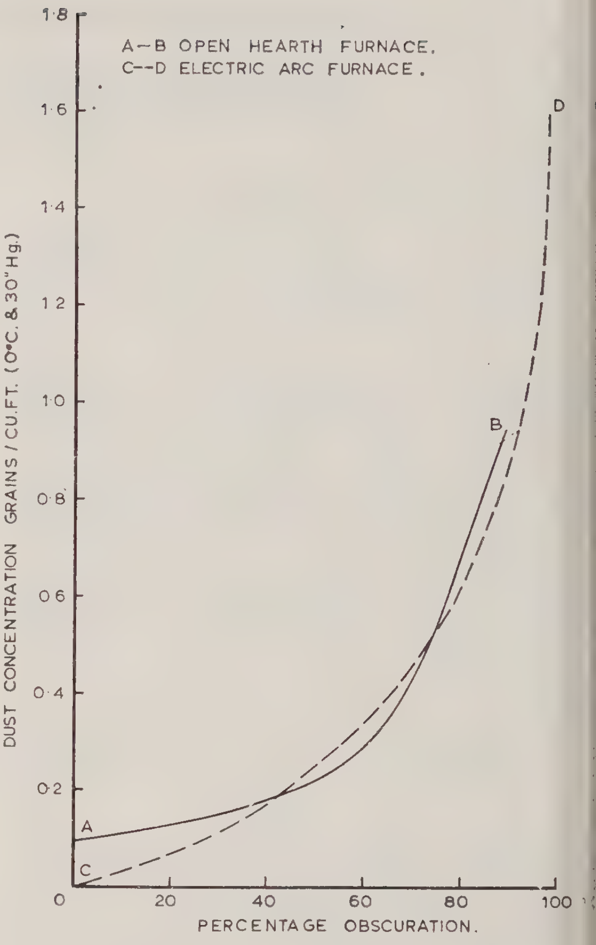
The high obscuration figures appearing on Figure 1 result from working on this wide chimney. The large distance between light source and photo-cell leads to considerable obscuration with relatively low dust loading. To a ground observer, the stack appeared almost clear when 30 per cent. obscuration was indicated.

It was possible with experience roughly to relate smoke density with furnace practice and bath conditions and this made it possible to choose times for gravimetric measurements when obscuration conditions were likely to remain steady during the sampling period. A standardised isokinetic technique was used to obtain all the samples.

Results

The relationship between percentage obscuration and dust content of the gases from the open hearth is shown in Figure 2, line A-B. It will be noticed that the line is curved and it will be evident also that the results are a function of the optical geometry and stack conditions at the sampling point.

In order to obtain a more useful criterion, the chimney diameter and gas temperature have been eliminated and the results replotted in Figure 3 as optical density per foot at 0°C. (D) versus dust loading per cu. ft. of gas at N.T.P.



DUST CONCENTRATION AND PERCENTAGE OBSCURATION.

FIG. 2.

$$D = \log_{10} \frac{\text{I incident}}{\text{I emergent}} \text{ for 1 foot thickness.}$$

Figure 3, line A-B shows the optical density to be approximately proportional to dust loading, and statistical analysis shows the line to be highly significant. Individual results have not been plotted, but lie within the band shown. It is possible that scatter was caused by differences in particle size distribution with different phases of the melt. At the time these experiments were made, no suitable technique was available for particle size estimation.

A second series of experiments on the same furnace some months after the first, confirmed the line A-B. The work was extended by a further series on a small electric arc furnace. Oxygen was used in this furnace for refining and was blown into the metal bath for short periods until the required carbon level was obtained.

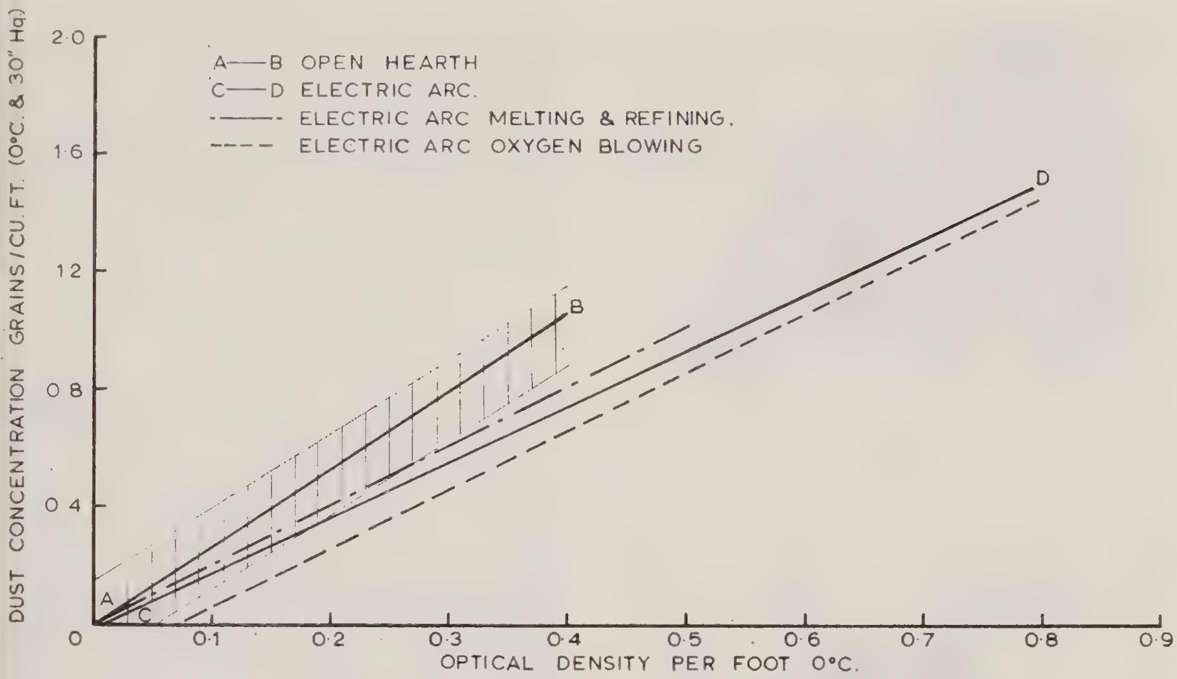
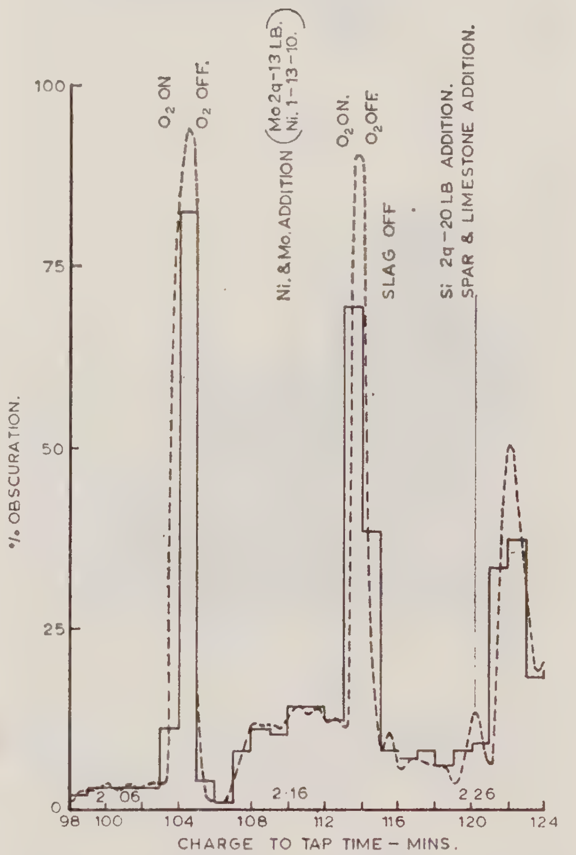


FIG. 3. OPTICAL DENSITY AND DUST CONCENTRATION.

Obscuragrams were plotted as with the open hearth furnace and in the same way it was found possible to choose appropriate sampling periods with reasonably stable conditions. Part of an obscuragram for this furnace is shown in Figure 4; it shows the period during oxygen blowing when very high fuming rates occur.

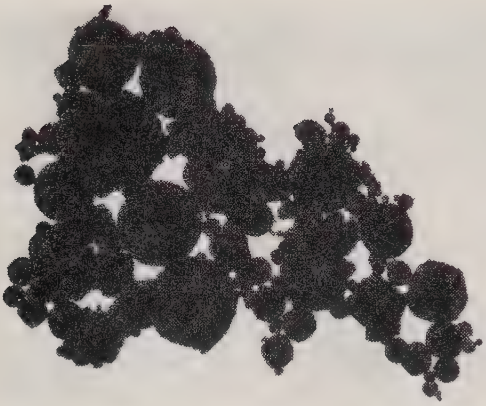
The relationship between fume emission and obscuration is given by line C-D in Figure 2 and fume emission versus optical density by line C-D in Figure 3. The difference in slope between lines A-B and C-D on Figure 3 is probably due to different size distributions of the dust emitted from the two furnaces.

A method has been developed enabling electron micrographs of the collected dust to be made so that an estimation of size distribution is obtainable. Micrographs of samples taken during the three stages of the electric arc process—melting down, oxygen blowing and refining—are shown in Figure 5. These show that there is a difference in particle size distribution; emission during melting and refining being coarser than that during oxygen blowing. Subsequent analysis of the line C-D, Figure 3, shows slightly different

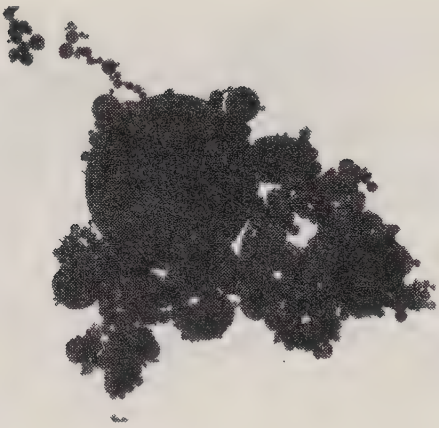


OBSCURAGRAM FOR ELECTRIC ARC FURNACE DURING OXYGEN BLOWING

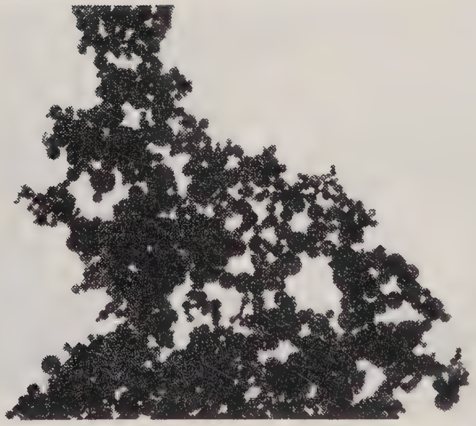
FIG. 4.



Melting



Refining



Oxygen Blowing

*Fig. 5. Samples of dust collected in the Extraction Duct of the Electric Arc Furnace (Mag: X*7.500)

best fit lines for the appropriate results. These are indicated in the figure. The relationships are consistent with the particle sizes shown in Figure 5, i.e. larger particles during melting and refining give a lower optical density per unit mass than does the fine fume emitted during oxygen blowing.

Conclusion

From these experiments it is clear that for normal practice with either the electric arc or open hearth furnace it is possible to estimate the dust concentration in the waste gas from measurements of optical obscuration. Relationships for the two furnaces examined were similar. The slight difference in the slopes of the lines A-B and C-D may be explained in terms of different size distributions from the two processes, and it is likely that similar differences would be found among individual open hearth or electric plants. Further work of this nature is in progress and laboratory experiments have been planned to examine the specific effect of particle size distribution on optical density.

Acknowledgements

The authors thank Mr. F. H. Saniter, O.B.E., Director of Research, The United Steel Companies Limited, for permission to publish this paper.

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Discussion

G. Nonhebel, (Individual Member), said that he had been asked to act as rapporteur on the research papers as well as to open the discussion. He proposed to discuss the valuable research papers in Group 1 and also the last paper in Group 3 which was really a research report.

Mr. Meade had provided data on the number of days in the year when the atmospheric conditions were such that fog and smog might develop. It is important to note that the tables give the maximum number of days in the year but it by no means followed that fog would necessarily develop. There are also a few other conditions when meteorological conditions could give fogs lasting only, however, about eight hours and this period was so short that dangerous smog would not then be developed. Mr. Nonhebel also commented that the Meteorological Office has been giving workers on atmospheric pollution much more meteorological data of value since the Beaver Committee was appointed.

Mr. Jarvis' paper gave a statement of the measurements around power stations that are being made by the electricity industry. In Mr. Nonhebel's view, lead peroxide meters were not suitable for measurements of SO_2 in terms of its effect upon health. Many more volumetric measurements were required for periods as short as 15 minutes. A suitable but expensive instrument for such measurements had now been developed by Cummings and Redfearn and he (Mr. Nonhebel) suggested that the D.S.I.R. should make some special studies of volumetric SO_2 concentrations in smoke controlled areas and around groups of industrial chimneys during meteorological conditions when it would be expected that ground-level concentrations of SO_2 would be high.

Mr. Nonhebel said that he could not comment on the measurement and analysis techniques for benzpyrene described in a paper by Mr. Howe, but he had found the last part of the paper most interesting. Measurements had been made which indicated that the amount of solids in the flue gases from a water-tube boiler burning 3,000 sec. oil amounted to $1\frac{1}{2}$ tons solid per 1,000 tons fuel burnt or about 1 grain/ft.^{3} flue gas. These solids were not innocuous dust but consisted of particles, some of which aggregated to smuts. Similarly, there were 1·8 tons per 1,000 tons heavy fuel of gaseous condensible "oil" in the flue gases. Partly-burnt oil was responsible for the smell from some oil-burning installations. The measurements made by Mr. Howe were presumably made by well-operated clean plant and no doubt the figures quoted would be increased substantially when the burners became dirty and partly choked as they inevitably did in operation. Mr. Nonhebel said this was the first paper he had seen which gave such quantitative information and he hoped that more measurements would be made under varying commercial conditions. The deduction that he made from the paper was that there was scope for improving burner performance so that there was absolutely complete combustion, as was achieved in the odourless paraffin domestic heater.

Mr. Nonhebel then turned to a discussion of the sixth paper by Dr. Craxford on the accuracy of the measurement of air pollution. He had found the information in it most disturbing. It was most important to distinguish between the precision of measurement which meant its reproducibility, and its accuracy which meant that it gave the true value of the measurement with no bias. He thought that the variability of the figures for deposits soluble in water was because of the variable solubility of fine ash in rain water.

Mr. Nonhebel criticized the use of stains for measuring smoke. The method was excellent when practically all the suspended matter in towns came from badly operated industrial and domestic coal fires, but today there were numerous furnaces such as power stations and cement works which discharged a pale buff coloured dust quite free from soot and tar. He favoured development by the D.S.I.R. of apparatus for measuring the solid content of air in terms of weight and means for examination of the sizes of the particles in the atmosphere. He thought it was a waste of time continuing with further investigations of the smoke stain method. He had already given his views on SO_2 measurements in his discussion of Mr. Jarvis' paper.

Mr. Williams's paper was most important in that it showed that ventilation of the air in our towns came from above as well as from the sides and consequently it was wrong to oppose a smoke-controlled area on the grounds that it would not be effective because the wind would blow in smoke from a surrounding neighbourhood.

Nevertheless, the minimum size of area should be larger than half a mile in diameter.

Mr. Williams's valuable paper was subject to the criticism that it assumed that gauges were uniformly distributed round the town for which measurements were reported. Unfortunately it was too expensive to install gauges so as to give a statistically accurate picture of atmospheric deposits in a town and many of the sites for gauges were chosen to give what readings indicated to be dirty spots.

Mr. Nonhebel said that the painstaking analysis of trends in pollution given by Carroll and others was not completely convincing though he confirmed from his own personal observation that Central London was now cleaner than towns on its periphery. He also confirmed that Central London was now far freer from smoke than its suburbs. He suggested that a comprehensive series of measurements should be made with deposit gauges and volumetric SO_2 gauges in the large smokeless zones of Nottingham, Bradford and City of London.

In conclusion, Mr. Nonhebel said he would like to repeat that SO_2 measurements should not be considered alone but always in conjunction with smoke measurements, since there was plenty of evidence to show that, in the absence of smoke, quite high concentrations of SO_2 could be tolerated by human beings without difficulty; much lower concentrations of SO_2 damaged vegetation, and SO_2 was responsible for the corrosive nature of the atmosphere of towns resulting in the decay of buildings.

Mr. Nonhebel said he thought the last paper of Group 3—Industrial Reports—by Messrs. Christie and others on measurement of dust emission from steelmaking furnaces should also be considered as a research report and in this connection he asked that Mr. W. F. Carey should report on some of the studies he was making.

W. F. Carey said he found that he had a common cause with the writers of the paper, " Measurement of Dust Emission from Steelmaking Furnaces " because they were all interested in treating effluents so as to avoid nuisance without incurring unreasonable expense. They rightly considered that there were two sorts of nuisance:

(*a*) That due to deposits on the ground.
(*b*) Obscuration on the sky.

On pp. 71-2 they stated that " To eliminate the visual effect and achieve a clean stack meant that the effluent concentration must be reduced to about 0·05 g./M^3."

He wished to comment as follows:

The values for projected area in Table I of the paper meant that the projected area of 1 cm^3 of solids divided into 1 micron particles is 1·5 M^2 or 0·75 M^2 for 2 microns. Thus the obscuration when viewing 1 $ft.^3$ of gas containing 0·05 grains of 1 micron particles was 1·31 per cent. In the same way the mean sizes which corresponded to Curves B and D on Fig. 3 were 1·4 and 1·75 micron; these values did not seem to conflict seriously with the micrographs. Thus it appeared that the mean size of the chimney effluent was about 1·6 micron; if the diameter of the stack was taken as 15 ft. the 1 per cent. obscuration of the exit = $15 \times {}^{1.3}/1{\cdot}6$ = 12 per cent. at its diametral section.

Mr. Carey went on to say that he had carried out experiments with images of plumes made by suitably spaced brown dots on paper sheets: these showed that plumes which obscured less than about 10 per cent. of the light were difficult to detect. That afforded rough agreement with the results reported in the paper.

However, he suggested that it was illogical to specify nuisance in terms of some fixed dust concentration at the stack exit such as 0·05 g./M^3 also it might prove to be very expensive to do so.

It might be reflected that the fine dust in a smoke plume was not removed when the plume vanished, but drifted across the countryside in the wind until it was blown out to sea. During this process the dust was continually diluted by the atmospheric eddies; the plume would vanish when it became so diluted that the eye could not perceive the contrast between the plume and its background: as a corollary plumes would be found especially conspicuous on the rare occasions when they were viewed longitudinally and much more persistent in low winds than in high. It was easy to reduce the length of the plume formed in low winds by arranging to discharge the flue gases so that they became diluted with air. Such premixing was particularly effective with hot flue gases which even in unfavourable inversions would be diluted by at least 100 volumes of air before their buoyancy was destroyed. The following sequence of treatments might therefore offer advantages:

(*a*) Grit catchers to remove particles greater than 30 microns so as to avoid deposits in the neighbourhood.
(*b*) Precipitators to remove two-thirds

of the fines less than 30 microns (if necessary).

(*c*) A stack discharge arranged to dilute the plume so that the surface of the dust would occupy less than 10 per cent. of its area.

To strive for an invisible exit near the mouth of the stack might be a waste of effort on occasions when the public interest could be served equally by making arrangements to discharge the gases so that they were diluted sufficiently to disappear. The principal uncertainty to be encountered when adopting such a scheme would lie in estimating the value of the vanishing obscuration. Field tests with light obscuration meters seemed to be an admirable supplement to paper patterns for exploring this important question; it was to be hoped that the writers would be able to report further results in due course.

R. E. Waller, (Medical Research Council), enquired whether Miss Carroll and her colleagues could add any information regarding the concentration of smoke and sulphur dioxide during the period 1959-60. He said that he was particularly interested in the trend of these pollutants in the London area, and whilst he could confirm the observations regarding a continuous decline in smoke concentrations he considered that the rise in SO_2 during 1958-9 might have reflected no more than a random variation in weather conditions. Mr. Meade, in his paper, had mentioned that the winter of 1958-9 had given rise to many periods of widespread " smog " and this may have been sufficient to have increased the mean annual concentration of each pollutant above the normal level. In this case, the results might suggest an even steeper fall in smoke concentration with the concentration of sulphur dioxide remaining reasonably constant.

P. Draper, (Shell Mex and B.P. Ltd.), referring to the paper by Carroll, Craxford, Newell and Weatherley, said that he considered it an interesting paper of statistics which showed quite clearly some trends over a seven-year period of review. He thought the comparison of calculated and measured emission of smoke and sulphur dioxide were particularly interesting provided one remembered that the calculated sulphur oxide figures were a measure of how much fuel had been consumed while those for smoke showed how incompletely it had been burned. Complete combustion would give zero smoke.

Beyond that Mr. Draper confessed to being very disturbed at some of the conclusions drawn by the authors particularly the statement " emission of sulphur dioxide from the large coal-burning plant and from domestic heating have been decreasing sharply but the good effect of this at ground level has been more than outweighed by the increased emission from industrial oil burning plant. Although, in the last five years the total emission has decreased, the ground level pollution has increased. This alone is proof that the dispersion from the chimneys of the new oil burning plant is inadequate." His own calculations showed that although the figures in Table 1 indicated that on a tonnage basis the fuel consumption in Great Britain had fallen from 1953 to 1959 by about 2 per cent. this was due only to the higher heat content and efficiency of usage of oil as compared with the solid fuels, thus if the oil tonnage were converted to the equivalent weight of coal then it was found that the fuel consumed had in fact increased by about 3 per cent. He found that this was accompanied by a calculated increase in sulphur dioxide emission of about 2 per cent. and this figure was also quite close to the Department of Scientific and Industrial Research measured ground level increase.

Thus Mr. Draper found that the conversion to oil far from being responsible for an increased overall rate of emission of sulphur oxides had in fact achieved a noticeable if slight reduction of rate. Furthermore this finding would be expected on a theoretical basis.

Mr. Draper hoped the authors would forgive him for objecting to the rather emphatic but unrealistic conclusions which he thought detracted from an otherwise excellent paper.

Dr. Albert Parker, (Royal Society of Health), expressed his appreciation of the useful and excellent work of his former colleagues of the Fuel Research Station (now of the Warren Spring Laboratory) in studying over a number of years the records of the quantities of the fuels used for different purposes, and the results of measurements of air pollution by smoke and sulphur dioxide in Great Britain and in the London area. He had also read with much interest the useful paper on the accuracy of the instruments normally used for measuring pollution.

He doubted, however, whether it was justifiable to draw from the available data some of the conclusions in the paper by Miss Carroll, Dr. Craxford, Dr. Newell, and Mrs. Weatherley on " Trends in the Pollution of the Air of Great Britain by

Smoke and Sulphur Dioxide, 1952-9." He referred particularly to the conclusions drawn from the estimates of the quantities of sulphur dioxide emitted in the London area, combined with the results of measurements in that area of the concentrations of sulphur dioxide in the air near ground level.

The estimates of the quantities of sulphur dioxide emitted in the London area had been based on the average sulphur content of coal and of two types of oil for the whole country. The sulphur content of British coals varied widely from less than 1 per cent. to more than 3 per cent. and the overall average for the coals burned in the London area may or may not differ appreciably from the national average; the data were not available to settle this point. In addition, there were no data for the quantity of coal consumed by works in the London area each burning less than 1,000 tons of coal a year.

In determining the concentration of sulphur dioxide in the air, the results from the lead peroxide instrument, which were ordinarily expressed in milligrammes of sulphur trioxide per 100 sq. cm. of lead peroxide per day, had been converted to microgrammes of sulphur dioxide per cubic metre of air by multiplication by the factor 111·5. In the experiments described in the paper by Dr. Craxford, Dr. Wilkins and Mr. Slimming, it had been found that the factor for the yearly means for several lead peroxide instruments ranged from 63 to 172, with an overall average of 112. It may be that this overall average varied from one group of instruments to another and from year to year, owing to differences in local meteorological and other conditions.

It was doubtful, with so many variables not precisely known, and the limitations of the estimates of emissions and of the methods of measurement of pollution, whether the average results for any one year could be relied upon to be nearer than about 10 per cent. to the true value. Yet the conclusions from the data for emissions and concentrations of sulphur dioxide in the air of the London area seemed to have been drawn mainly from differences from year to year of no more than 10 per cent.

Apart from the doubt he had expressed about the justification for some of the conclusions, he (Dr. Parker) considered that the papers from the Warren Spring Laboratory described an enormous amount of useful and interesting work, which should be continued and intensified.

E. W. Wignall, (Secretary, Coal Utilisation Council), referring to Mr. Baxendale's paper on the modification of side oven ranges by means of conversion units, drew attention to the availability of such units from a number of manufacturers. He suggested that those supplied by the original makers of the ranges to be converted might be more effective than those intended for a variety of ranges, of various dimensions. He added that some old ranges, with wide brick-built flues, might cook quite satisfactorily on coal, but not be capable of being successfully converted for using coke. In such cases, householders who wished to continue to cook by solid fuel ought to be allowed a grant on a complete modern combination grate—which might well cost less than converting the range into an open fire and adding an independent gas or electric cooker.

Councillor Ginty, (Eston), began by saying that he represented a Teesside Urban District Council, which was a " black area," because of the industrial and domestic smoke nuisance, consequently he was not concerned with the pollution which occurred about the threshold of discernity, but about the problem of gross pollution. How could they hope to convert the people to a clean air campaign, and conscience when the iron and steel processes belched their filth over the township. On this issue he would like to make a plea for better communications between the Alkali Works Inspector, and the Public Health Inspector. They had a limited amount of co-operation, but he would like to see a more business-like understanding *officially*. Councillor Ginty went on to say that he had read the opening paragraph of the paper by Messrs. Christie, Pengelly, and Gray and that statement might be true, but the waste gases from coke ovens, blast furnaces, and steel plants, and the effluvia emitted by ore sintering plants was far from reasonable or practicable within the meaning of the operative clauses. With the inception of Tonnage Oxygen process he shuddered to think of the pollution that would ensue. Prevention now was urgent, indeed crucial. Finally, he would like to add that the iron and steel industry provided the bread and butter for many families on Teesside. He wanted to see it progress and develop but the people of Teesside did not want bread, butter and grit.

G. H. Cooper, (Chief Public Health Inspector, Ashton-under-Lyne) said that as a Public Health Inspector and Hon. Technical Officer to twenty-five local authorities co-operating in the investigation of atmospheric pollution, he was particularly interested in the paper prepared by Drs. Craxford, Slimming and Wilkins with particular reference to the volumetric analysis method of measuring atmospheric pollution, and he wanted to know whether in the opinion of the authors greater significance could be attached to results from this instrument if meteorological data was more carefully recorded nationally in accordance with a standard form of procedure. He also wanted to know whether they would recommend as a regular practice the use of a 1 in. filter on the volumetric instrument during the summer period from April to September and the use of the 2 in. filter during the winter period. Finally he asked whether any further information was available on a more suitable filter medium than the Whatman No. 1 filter paper.

A. C. Hazel, (Hurseal Ltd.), suggested that the annual Clean Air Conferences were becoming too scientific. It was seldom possible to get several scientists each representing a different fuel, to agree on anything which might be detrimental to the fuel they so ably represented. Obviously, the technical problems associated with clean air required discussion, but if this had to be at the Annual Conference could it not be on the last day thus enabling those delegates who were more concerned with the promotion of clean air than deciding what constitutes smoke—they already knew—to return from whence they came.

All fuels provided comfort, some created a nuisance in so doing, some provided comfort without discomfort and the virtues of these fuels should be emphasized by the Society. Surely the real job of the Society was emphasizing and publicizing the virtues of clean air and the fuels that reduced atmospheric pollution. What was needed at these conferences was the provision of more information to local authorities on the advantages of clean methods of heating as regards comfort, equipment and fuel, persuading the public to fight nuisances of all kinds whether it be petrol fumes, smoke or dirt, and the continuous promotion of publicity of all kinds to achieve their rightful ends—clean air.

Miss Dorothy Boyd, (Individual Member), said she was particularly interested in the report on British Standard Coke. Whilst she welcomed a British Standard for coke, she deplored the variety of names used to market it. Whilst appreciating the scientists' need for recognizing the process by which a fuel was produced, it must be remembered that the method of production was not of interest to the average domestic consumer, whose yard stick was: " How will the stuff burn in my grate and what will it cost? "

It was interesting to note that the Peech Committee suggested that British Standard coke should not be supplied for use on old-fashioned grates.

Some smokeless fuels were advertised as being suitable for use on the old-fashioned grate, this was misleading, as they could not be so used with economy.

The final simple need was to convince the domestic consumer that solid smokeless fuels burned in the right appliance properly fitted were an economy in every way. When this fundamental fact was generally accepted the co-operation of the domestic consumer in implementing the Clean Air Act would be forthcoming.

J. W. Batey, (Sheffield and District Clean Air Committee), drew attention to the paper by Cooke and Eaton and said that if the industry would not take stronger action to supply coke to specification the position might arise when the Government would enforce a standard. A quality fuel was essential to the success of the smoke control areas, and a quality price was being paid for the fuel.

Mr. Batey also drew attention to the fact that it was still possible to buy an approved appliance out of the recommended list of solid fuel appliances and obtain a firegrate with $\frac{1}{2}$ in. bar spaces. This matter should be put right as soon as possible.

Also he drew attention to the position that the Ministry will not allow more than five or six pounds as being the maximum price for a solid fuel approved type of appliance. A more efficient and much more expensive type ought to be available to people who have the good sense to want a better and more efficient article. They must not flood the country with less efficient appliances.

Authors' Replies

W. D. Jarvis and D. S. Wilson, replying to Mr. Nonhebel's comments on their paper, wished to point out that the lead peroxide instrument was developed by D.S.I.R. to measure the activity of SO_2 in air and to assess its possible effect on materials used in building construction. The instrument, being exposed for a month at a time, gives an arbitrary measure of the average SO_2 concentration in the vicinity. High concentrations of SO_2 which may occur only for short periods of time, and which may be harmful to health, are included in the average concentration observed. For this reason alone the lead peroxide instrument does not provide a satisfactory measure of SO_2 in terms of its effect on health.

The apparatus developed by Cummings and Redfearn at Central Electricity Research Laboratory was specifically designed to measure short term concentration of SO_2 in air. Using this apparatus the Board have carried out surveys around several power stations to measure the maximum concentration of SO_2 at ground level, and to relate the distance downwind at which the maximum concentration occurs with chimney height.

E. L. Howe, replying, said that until recently little data were available on stack emissions from oil fired plant particularly with regard to the quantity of solids emitted and their character, *e.g.* most tables when referring to oil firing quoted terms like "*small*," "*negligible*," or even simply present a —. The main object of their work was to fill in this apparent gap in their knowledge of factors affecting air pollution, not only for solid emission, but also for other exhaust constituent from oil fired plant. The particular work on 3:4 benzpyrene, with which this paper was concerned, was only a small part of their overall programme.

In connection with Mr. Nonhebel's comments on the solid emission from a water tube boiler, burning 3,000 seconds fuel oil, Mr. Howe said he would like to correct any impression he may have created that 1½ tons of solids emitted per 1,000 tons of fuel burnt was a high figure in comparison with other sources of pollution. This quantity was equivalent to 0·04 *grains per ft.*^{3} *of flue gases at N.T.P.*, not 1·0 grains per ft.^{3} of flue gas as suggested. Concentrations of such low order could only be achieved on solid fuel appliances by the installation and efficient operation of grit arresting and dust precipitation plant. Furthermore, the particle size of solids from oil fired plant was extremely small; generally 90 per cent. by weight was less than 20 microns in diameter. Thus, the solids from oil firing were easily dispersed and did not fall locally. Agglomeration of solid particles to form smuts would only take place if low temperature regions existed in the exhaust system where sulphuric acid condensed to act as a catcher for solids. Smut formation was a special problem and could be eliminated in most circumstances by correct exhaust system design. In the case of steel chimneys the problem had been eliminated on many installations by fitting suitable lagging or aluminium shielding.

He would also like to correct any impression that their tests were made under special operating conditions with clean plant. The work was conducted during normal operation of the appliances when fulfilling the duties for which they were installed.

The figure of 1·8 tons of condensible "oil" in the flue gases per 1,000 tons of heavy fuel oil burnt, quoted for the water tube boiler by Mr. Nonhebel was incorrect. Table 4 of his paper showed that the figure quoted should have been 0·35 tons of condensible "oil" per 1,000 tons of heavy fuel oil. Referring to Mr. Nonhebel's point concerning unburnt "oil," he would like to point out that the sampling conditions for 3:4 benzpyrene were extremely severe in that the temperature of the sampled gases was reduced to −65°C. in the freeze-out trains. This means that the term "oil" covered all unburnt hydrocarbons condensing at temperatures down to −65°C. The majority of the materials collected would undoubtedly be in the vapour phase at normal atmospheric conditions. He would like to ask Mr. Nonhebel, "Have samples been taken from the exhausts of coal fired plant under such stringent sampling conditions?" He felt quite confident that if the equipment described in his paper were used on coal fired appliances, either industrial or domestic, unburnt condensible materials would be detected. In particular he would expect the quantities from open fire flue gases to be very high.

He would like to make it clear that it was never intended in this paper to make comparisons with other types of fuel. However, since solid fuels had been mentioned in discussion the following figures were perhaps of interest:

(*a*) *Solid Emission*

1. The estimated average solid emission from coal firing in Great Britain was of the order of 0·8 per cent. by weight of fuel burnt.

2. Solid emission from coal fires could be as high as 2·9 per cent. by weight of fuel burnt.

3. With reasonable operating conditions oil fired appliances should not emit more than 0·2 per cent. by weight of fuel burnt as solids.

(*b*) 3·4 *Benzpyrene*

1. In soot from coal firing concentrations of 3·4 benzpyrene as high as 1,000 μg/gram had been detected.

2. In solids from oil firing concentra-

tions of 3·4 benzpyrene were likely to be less than 1 μg/gram.

F. P. Williams, in reply to Mr. Nonhebel's comments, said that, although he agreed that many of the gauges had possibly been sited in what were thought to be dirty spots, most local authorities would probably consider the dirty spots to be in areas of industrial activity. Thus, any bias in the selection of sites would be expected to be towards industrial smoke and this made the relationship between smoke pollution and domestic coal consumption even more remarkable. On this basis, he thought it was reasonable to assume that the smoke pollution pattern formed in any town would, in general, be largely dependent on the distribution of population densities, or, more accurately, because of differing social habits, on the distribution of domestic coal consumption densities within the town.

Dr. S. R. Craxford, replying to Mr. Nonhebel, said that methods of measuring smoke based on the use of stains had been considered by an international OEEC Working Party and they had agreed that, although subject to calibration errors, the method was basically the most suitable for general use. In conjunction with the Working Party the Warren Spring Laboratory were now investigating the calibration of the instruments for different towns and different localities. The results of this work would show what substance there might be in Mr. Nonhebel's criticism. Referring to volumetric measurements of sulphur dioxide, Dr. Craxford said that the Warren Spring Laboratory were, in fact, now making preparations for surveys around individual chimneys and a simple volumetric apparatus, triggered off by an alarm clock, had been developed for such short-period surveys.

Dr. Craxford said he agreed with Mr. Nonhebel that it was a rather dangerous exercise to attempt to draw conclusions on trends and averages from observations that had come into being in a haphazard way and were not statistically planned from the beginning. One of the objects of the new National Survey that was now being launched was to enable this type of calculation to be made with precision, but, in the meanwhile, he thought that, considering the large number of instruments now in use, the broad outline of the picture obtained by their use would not be far wrong.

Replying to Mr. Draper, Dr. Craxford said that the sentence Mr. Draper objected to referred to London alone and not to the whole country as Mr. Draper had assumed. It followed directly from Figure 8 which would be very difficult to interpret in any other way. Indeed, if it had been possible to include the figures for emissions from commercial premises (figures which had since come to hand) the argument in the paper would, in fact, have been strengthened. However, Dr. Craxford said that he had not stated, and had certainly not meant to imply, that it was the change-over from coal to oil that had led to increased pollution by sulphur. He agreed entirely with Mr. Draper that for a given output of useful heat there was little to choose between the two fuels as far as sulphur was concerned. If the heating and power load now taken by oil had been taken by coal, pollution by coal would probably have been about the same.

Replying to Dr. Parker, Dr. Craxford repeated what he had said to Mr. Nonhebel about trends and conclusions, and he added that while he agreed wholeheartedly with Dr. Parker on the danger of using data from lead peroxide instruments, he had considered that for the present purpose there was reasonable safety in the very large number of gauges in use. Dr. Craxford subsequently replied in writing that he had since had the data for daily measurements by the hydrogen peroxide method, up to and including 1960, worked up in the same way and had put them into the final printed version of the paper to replace the tables based on the lead dioxide method. The results for the whole period, as given by this more precise method, had, in fact, shown that there was no detectable upward or downward basic trend (after the effects of weather had been eliminated) either for London or for the country as a whole. He also stated that data and estimates had now come to hand concerning the sulphur contents of the different types of oil now in use and the amounts of oils used for heating commercial premises, etc., but that, as expected, the changes in total emissions had been very small and had had no effect on the argument.

Dr. Craxford replied in writing to Mr. Waller and stated that he had since had the smoke and sulphur dioxide data calculated for 1959-60 and, as Mr. Waller had surmised, these data showed that concentrations of both pollutants had been abnormally high in 1958-9 both for London and for the country as a whole. These data have been included in the present printed version of the paper.

Dr. F. J. Eaton said he welcomed the remarks made by Miss Dorothy Boyd particularly as those of a housewife and one whom he knew to be an enthusiastic member of the Society. As a housewife he felt sure she must purchase many commodities under a " brand " name and knew just which brand suited her particular requirements. He was at a loss to understand why she deplored the use of brand names for fuels. Surely with the very large number of appliances for which some fuels were suitable and others not, the need for a brand name was very important. As Miss Boyd stated, the yard stock was " How will the stuff burn in my grate." This is actually what a brand name will indicate, thus the Peech Committee mentioned by Miss Boyd states in effect that Gloco would not be suitable on the old-fashioned grates, but Cleanglow and Phimax, etc., would be quite suitable. It should be realized that the British Standards Specification only gives limiting values and that the named brands of fuel, while complying with the Standard, are more consistent in quality and have a higher reactivity than the minimum requirements specified. He did not agree that there were too many named fuels; four named brands only were mentioned in the paper, Gloco and Sebrite for the improved open fire or the heating stove whilst Cleanglow and Phimax could be used satisfactorily on the stool bottom grate as well as on the more modern open fire appliance.

He agreed with Miss Boyd on the need to convince the domestic consumer that solid smokeless fuels burned in the right appliance, properly fitted, were economical and it was most important that everybody and particularly the members of the Society, should make this known as widely as possible.

Mr. Batey had asked why the gas industry had not taken a stronger action to supply coke to the specification. He thought it was clear in the paper that named cokes conforming to the specification were now being supplied by 11 of the 12 Area Gas Boards. The supply position too of the more reactive Cleanglow and Phimax was improving and the rate of increase was dependent solely on the supply of suitable coals. These coals were washed so that the resultant fuel had a lower average ash content which resulted in a cleaner fire. His information was that British Standard coke had always been made available by all gas boards to the smoke control zones within their areas.

With regard to the need for a ⅝ in. fire bar space on the open fires, he could assure Mr. Batey that the forthcoming list of recommended solid fuel appliances would only name those which had a ⅝ in. fire bar space. He agreed that the list had contained names of appliances which were only supplied with ½ in. bar spaces and that it had taken a very long time for this important change to be made.

D. G. Wilson, replying, said:

(*a*) Great stress must be laid on the characteristics of the areas surveyed. These were all corporation estates where the use of smokeless fuel was compulsory by tenancy agreement, *i.e.* they were true smokeless zones rather than smoke control areas. The method of their creation had evoked much less criticism and antagonism than was sometimes found in the more recent use of the smoke control area procedure.

(*b*) The paper recorded what was, in fact, a " success story " of how a large industrial city had energetically pursued its own smoke abatement policy. The satisfactory results achieved could largely be ascribed to the presence of certain essential conditions. Firstly, the right fuel: the areas surveyed had been for many years served by a continuous vertical coke of B.S.S. quality. (In passing it would have been noticed that no consumer complaints were recorded about excessive moisture in coke. Indeed, the inverse of this—the presence of dust—was occasionally complained of.) Secondly, the right appliance: the corporation had provided a satisfactory coke burning appliance with the proper ⅝ in. fire bars and with integral gas ignition. The appliances were, in general, properly fitted and reasonably maintained. Thirdly, the right technique: in half of the area surveyed smokeless fuel had been used for five years or more—ample time to overcome initial prejudice and to acquire the different technique which is undoubtedly necessary in the change from coal to coke. The formula could therefore be deduced that:

Satisfaction = the right fuel and
appliance plus experience

(*c*) With regard to the remarks of Mr. A. C. Hazel, the author agreed that all fuels had their virtues and their limitations and that in clean air developments there was clearly room for many types of fuel and appliances. The price of the different fuels and appliances, together with the individual's preference would decide the pattern of usage.

A. Harrison Slade, replying, spoke on Mr. Nonhebel's reference to abnormally wet washed smalls delivered by road. There had been a widespread improvement in the last two to three years resulting from improved washery operations, the use of drainage bunkers and centrifuges both on new and old washeries. This improvement had been freely acknowledged by consumers up and down the country and had been contributory to the popularity and growth in the volume of road deliveries.

Regarding dust emission, Mr. Slade accepted Mr. Nonhebel's point that while one must consider the dust concentration in chimney emission, what mattered most in the last resort was the amount of dust which reached the ground.

Regarding Mr. Nonhebel's remarks on the need for better technical service by the Coal Board, in connection with grit arrestment in particular, he would like him to be aware of the fact that this had already been recognized and put into practice this year by greatly expanding the number of fuel technologists who were now actively at work in the field. These men were qualified fuel engineers with wide experience of grit emission and its arrestment and were competent to advise consumers on all its aspects.

He agreed heartily with Mr. Nonhebel on the need for a published technical appraisal of equipment on the market for grit arrestment and he would exert any influence open to him to bring about such a publication.

INQUIRY INTO THE WORKING OF THE CLEAN AIR ACT

Reports on the Questionnaire

INTRODUCTION

ON the proposal of its Parliamentary and Local Government Committee the Executive Council of the Society decided to seek information on how the Clean Air Act was working in practice, and to that end submitted a Questionnaire to all local authorities in England, Wales and Scotland. A draft Questionnaire was first used in a pilot inquiry carried out among a small number of local authorities. As a result a few amendments were made and the final Questionnaire was then printed and sent out on March 1st, 1960.

1,053 authorities completed the Questionnaire, which called for replies consisting partly of statistical information and partly of comment. From the former the tables which accompany the Reports that follow have been prepared. The comment naturally varied very widely, some being capable of classification into groups and some being of individual interest and importance.

From Table 1 it will be apparent that a high percentage of each type of local authority returned the Questionnaire, and the results may therefore be taken as representative. Even in those two classes where the percentage return is lower than the general average, it is rather higher than is frequently experienced in this type of inquiry.

In the main, the results seem to provide valid answers to the questions asked, but there was obvious misunderstanding of question A(iv), and comment has been excluded. Question G(i)(e), on the deterrent effect of concessionary coal, seems to have been overlooked by some local authorities in mining areas, and the table has therefore been restricted to those authorities who have introduced Smoke Control Areas. Where a general value-judgment has been called for—e.g. in G(ii)(c) and K(iii), relating respectively to public opinion in Smoke Control Areas and Press Attitudes, independent evidence exists which corroborates the findings of this inquiry. The finding of a favourable public opinion in Smoke Control Areas is supported by the recent report by Consumer Research Ltd. (see *Smokeless Air*, Autumn 1960), while the finding of generally favourable attitudes among the local Press is borne out by the very high proportion of commendatory press cuttings received by the Society.

The content of the questionnaire was both extensive and intensive, and considerable thought was given to the selection of a suitable method of analysis. Finally, it was decided to use a " Cope-Chatterson " edge-punched card. Returned questionnaire forms were first examined by an experienced member of the staff, numbered consecutively within each category of local authorities, and obvious inconsistencies were removed. A specially prepared index card was then numbered to correspond with the form, and temporary statistical assistants then entered on the card the statistical information and the presence or absence of comment relating to each question. When all the cards had been checked and completed, they were " needle-sorted " into categories suitable to the variable under examination. Comment was collated from lists of form numbers prepared in this way. The analysis and the preparation of the tables was directed by Mr. Nevard, assisted by other members of the Society's staff, and a small amount of temporary help.

A supplementary Questionnaire was sent out to a number of authorities on certain Sections of the Act on which they had given preliminary information, and in addition, a special Questionnaire was submitted to the Port Health Authorities. It is regretted that it has not been possible to report on this latter in this Preprint but it is hoped that a supplementary report will be available for distribution at the Conference.

Both the tables and the comments have been used as the basis for the two Reports that are presented, one by Dr. W. C. Turner, on Smoke Control Areas and allied information on the domestic aspects of the Act; the other by Mr. E. M. Birtwisle on the industrial aspects.

It should be pointed out that insufficient time has been available for the more exhaustive examination of the Questionnaire that the analysis showed might have been possible, e.g. classification of information and comment by regions, but it is thought that the Conference discussions might point the way to further work of this nature, and that possibly it might be useful to seek further information on certain details of importance.

Arnold Marsh, Director

PART ONE—THE DOMESTIC AND GENERAL ASPECTS

By

*W. C. Turner, M.D., B.S., M.R.C.S.**

THE unprecedented mortality during the " smog " of December 1952 in London was a disaster which aroused so much public and official interest that a special Committee was appointed by the Government to investigate the problem of Air Pollution.

After long patient research and consideration of voluminous evidence from many sources, it issued an Interim Report (H.M.S.O./Command 9011, 1953) and its Final Report (H.M.S.O./Command 9322, 1954) both of which gave impetus to a Private Member's Bill introduced to extend existing powers relating to smoke abatement. The time was opportune and the subject of the Bill so important that it was taken over as a government measure and it is now four years since the passing of the Clean Air Act in 1956. Designed to abolish smoke from the environment of our towns and industrial communities this Act introduced bold and ambitious administrative procedures, entirely new to both the Ministry of Housing and Local Government and Local Authorities.

In view of the long and dedicated interest of the National Society for Clean Air in legislation to rid the skies of smoke, it is not surprising that it was intensely interested, indeed impatient, to ascertain the results of this new legislation. To what extent were the new Smoke Control Areas being created under Section 11? Was there any difference in the response between different classes of local authority, e.g., County Councils, County Boroughs, Boroughs including Metropolitan Boroughs, Urban District Councils and Rural District Councils or in different parts of the country; had prosecution been necessary and was it effective? Were there difficulties in operating the Act or regulations made thereunder? What changes might improve the effectiveness of the Act? These questions all needed an answer urgently. After much thought and with some trepidation the Parliamentary and Local Government Committee of the Society decided to attempt to secure as much information as possible on the varied aspects of the working of the Act, by an elaborate Questionnaire sent to practically every local authority, with the hope that they would be willing to co-operate. There are 324 areas designated " black areas " by the Ministry of Housing and Local Government. The enthusiasm shown by the number of returns and the material submitted in response has been surprising, almost overwhelming. A preliminary survey of the returns showed that some points required further elucidation; encouraged by the early response a further supplementary Questionnaire was sent to selected authorities and again the response was magnificent. All local authorities will be provided with an analysis in due course. So many items of interest were brought to light that it was realized immediately that it was worthy of reference to the Conference and further that it would be necessary to devote more than one session for discussion. Much of the material appears in the Conference papers as tables.

For convenience it was decided to devote two sessions to this topic, an arbitrary but natural distinction being made between the effect of Smoke Control Areas on pollution from domestic chimneys and the effect of controls on industrial smoke.

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* Medical Officer of Health, Metropolitan Borough of Poplar.

In introducing this session, to be devoted to problems arising from domestic sources and, on behalf of the Society, I would like to take this opportunity of thanking all local authorities who co-operated and to congratulate them on their enthusiasm which was most heartening and without which this session would not have been possible.

Smoke is a principle cause of air pollution and there is little doubt concerning the importance of domestic smoke in loss of amenity and as a major hazard to health, particularly during the winter. The Clean Air Act 1956 is the first attempt in the world giving local authorities effective means of control over smoke from domestic stoves and fireplaces burning coal which makes half the total smoke in the air. This is to be achieved by establishing Smoke Control Areas in which smoke must not be discharged with the exemption wholly or conditionally of premises or furnaces burning coal efficiently, e.g., fully mechanized industrial furnaces and special appliances.

Although some criticism of the Act has been occasioned by the absence of measures to deal with gaseous products of combustion, particularly sulphur oxides, critical statistical analyses of the excess mortality during recent London fogs indicates that the increase in deaths above the average during these periods shows a much higher correlation and statistical significance with the increase in particulate matter than with any increase in sulphur compounds, and it may well be that the elimination of smoke, that is visible, suspended particulate matter, from the air may have a decisive effect in lessening ill health from respiratory conditions, the defence mechanism of the body appearing to be well buffered against the effect of the gases in the concentrations normally experienced in the air. Current research into problems of corrosion of metals also indicates the importance of presence of particulate matter, in accelerating the rate of wasting.

Comments on Tabulated Reports: Table 1

Of the 1,703 authorities circulated 1,053 (60·8 per cent.) submitted replies. The response was 100 per cent. from Metropolitan Boroughs and Scottish Counties of Cities and over 95 per cent. from " black areas." This is regarded as a favourable indication of the keenness of the local authorities in the worst affected areas to use the Act to the full.

Tables 2—10 inclusive

Comment on this group of the Tables has been omitted as the material covered is the subject of a special session dealing with the application of the Act to industrial premises.

Table 11—Smoke Control Areas

A total of only 125 Smoke Control Areas has been created by 67 authorities.† It is hoped that this rather disappointing figure is merely an indication of a slow start due to the size of the problem, the newness of the administrative procedure and the possibility of staff shortages. There are signs that activity in the pursuance of Clean Air is gaining momentum. Progress will have to be accelerated if a substantial portion of the 324 black areas is dealt with in the next few years. It is encouraging that there is some indication that this is a possibility from figures published in the Summary, (H.M.S.O. Command 1113, 1960).

It is felt that in the drive for better housing the acceleration and widespread benefit in the cause of Clean Air could be achieved if the installation of approved appliances, with an undertaking to burn authorized fuels, could rank for Improvement Grants. It might be administratively difficult to control but it is assumed that a householder wishing to gain the benefits of the improved efficiency of an approved appliance, would also wish to gain the full benefit by burning authorized fuel.

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† Based on the replies and at the date of return. The latest figure issued by the Ministry, to June 30th, 1960, is 157.

Table 12—Conversions

Taking into consideration the relative sizes and variety of different authorities it is an interesting observation that the majority are making Smoke Control Orders in areas including more than 500 premises. In the largest more than 5,000 premises were included in a single area in one County Borough. As was to be expected no rural districts have as yet made a Smoke Control Order.

Attention is drawn to the ratio:

$$\frac{\text{Number of conversions}}{\text{Total Premises}}$$

This was 81 per cent. for County Boroughs and only 24 per cent. in the Metropolitan Boroughs although more than two and a half times as many premises were included in the latter. Why this should be is not quite clear.

In considering the ratio

$$\frac{\text{premises in County Boroughs}}{\text{premises in Metropolitan Boroughs}} = \frac{1{,}7551}{4{,}5128}$$

with comparable figures for

$$\frac{\text{contraventions in County Boroughs}}{\text{contraventions in Metropolitan Boroughs}} = \frac{524}{110}$$

this seems to suggest that in spite of the much larger number of premises involved in London the householders have been more willing to conform to the requirements; whereas in less than half as many premises in County Boroughs more than five times the number of contraventions have been recorded. The answers to these conundrums are probably related in London to increased public awareness to the dangers owing to the frequency of exposure to smoke fogs, to conversions voluntarily carried out prior to the Smoke Control Orders, and to the extent of redevelopment in the area as a whole.

Table 13—Staff

This shows quite clearly that the majority of authorities use qualified Public Health Inspectors for the work, a few others using special staff.

Table 14—Concessionary Coal

This suggests that concessionary coal as a difficulty in creating Smoke Control Areas is a serious problem in only a few districts. This is a matter of politics and perhaps I ought to make no comment, but two points ought to be made. The first is that indigenous fossil fuels, including solid smokeless fuels made from them should continue to be used wherever possible and that when comparison is made with the proposed use of oil it should be made when the solid fuels are used with comparable efficiency in modern appliances. The other point is that with the ever increasing number of persons employed in nationalized industries and equivalent public utility bodies there can be little justification for privileges granted to the few and denied to the majority who ultimately have to pay for them.

Tradition dies hard but the " Truck " Act still operates and what is required is a comprehensive and realistic basic wage structure which relates the wage earned by each worker in every industry to the competence, skill required of him in his job, the hazard to which he is exposed and the importance of the work he does in relation to the community.

It is gratifying that so few authorities appear to have experienced difficulties which are really insurmountable. The advertising campaign for the " cosy coal fire " by the Coal Utilization Council and the action of certain coal merchants in organizing opposition to Smoke Control Orders and the importance of Smoke Control generally, is regrettable and to be deplored. To me it seems incomprehensible that the national bodies, the Coal Board, the British Electricity Authority and Gas Boards should be in competition with one another, and it is still hoped that one day we shall see emerging from the Government a definite fuel policy which should put matters right.

Table 16—Gas Ignition

The advantages of gas ignition are undoubted and now certain difficulties in this connection have been clarified by the Ministry of Housing and Local Government in Circular No. 28/60, giving guidance on " The use of sticks and paper in Smoke Control Areas " with provision for a " general exemption " or " individual exemption " of fireplaces in premises without a gas supply. There is a condition that only authorized fuels and kindling sticks and paper shall be used in the fireplaces.

Table 17—Exemptions

Comment on the cases granted " special exemption " in Smoke Control Areas shows that although this provision appears to be used in an intelligent way for a wide variety of plants with special problems where technical knowledge is at present unable to provide a solution, it would appear that there are instances where smoke is being permitted in the burning of waste materials in unsuitable appliances and in crude incinerators or in the open. Generally smoke from these sources should not be tolerated. Avoidable smoke is quite unacceptable in Smoke Control Areas and compliance should be insisted upon. The " exemption " provision should not be mis-used in these cases.

One can, however, have sympathy with traditional methods of food curing by smoking where a small quantity of light coloured smoke is almost inevitable.

Table 19—Garden Refuse Nuisances

The burning of garden refuse has given rise to some difficulty. Frankly I think this problem must be dealt with rationally. Wherever possible disposal should be by composting although this is not always practicable, particularly in London Squares with numerous large plane trees, the tough leaves of which do not rot down readily, even with accelerators, and also where there are canes and woody stems. The whole problem must be examined in proper perspective. There are irritant aldehydes in the smoke from garden bonfires but most of the " smoke " is in fact water vapour; if the combustion rate is accelerated this practically disappears. Generally the amounts of smoke are small, they occur in fairly open situations, even in towns, at a time of the year, autumn and spring, when atmospheric scavenging is usually vigorous and when fogs are unlikely. If gardeners still wish to continue the practice as it does help to destroy weed seeds and pests, they must be prepared to co-operate to minimize smoke. They should burn the refuse in small quantities at a time in a brisk fire on windy days and never during foggy days. Large quantities should not be allowed to accumulate or to be left to smoulder. We must not lose sight of the fact that the Clean Air Act is primarily a health measure and with the safeguards mentioned the risk to health from this source of smoke is slight and the true significance of the problem can be assessed.

There is, however, one very serious nuisance which is ritually perpetuated on November 5th, very frequently in times of fog, when not only the smoke and soot from bonfires is added to the murk but the chemical products of fireworks and explosives add their intensely irritating products. Although this tradition currently related to one Guy Fawkes, it is a perpetuation of pagan customs, and in these enlightened days there can be little excuse for continuing it at this time of the year.

Further comment on this Table is also included in the Industrial Report.

Table 20—Bye-laws

There is little doubt from the interest shown in the replies to this question that much importance is attached to the proper wording and interpretation and universal adoption of Model Bye-laws. The Ministry of Housing and Local Government have issued " Amendments to Model Bye-laws " Series IV Buildings (1953) Edition, and these have been incorporated in the London Building (Constructional) Bye-laws 1952 which came into operation in London on April 1st, 1960 and I am sure this bye-law has been taken up by many other authorities. Much can be done by the use of appropriate bye-laws intelligently applied but one must not be tempted to draft into bye-laws powers or provisions not contained in the enabling Act as this would render such bye-laws *ultra vires*.

From some of the comments it would appear that many apparent problems could be cleared up by common sense interpretation and application of existing provisions. The importance of adequate control and the proper fixing of approved appliances is, however, stressed.

Table 21—Publicity

The importance of the value attached to health education in Clean Air and its benefits is quite clearly indicated in the comments and in the variety of publicity methods being used by practically every authority. What is regarded as a very welcome and encouraging sign is that groups of local authorities are combining in this activity not only among themselves but with other bodies which can help; these include—apart from this Society—the Department of Scientific and Industrial Research, Government Departments, National Coal Board, Gas Boards, British Electricity Authority, Coal Utilization Council, British Coal Utilization Research Association, British Medical Association, National Institute of Fuel Efficiency Service, Solid Smokeless Fuels Federation, Women's Advisory Council on Solid Fuels, Oil Companies, Education Authorities and Institutes, in the publishing of booklets, pamphlets, and in fact, using every possible sound, visual and other aid. I am sure that one of the most effective measures is the solution of individual and personal problems by a visit from the Clean Air or Public Health Inspector and their attendance at small demonstration centres set up locally in areas to be included in Smoke Control Orders. Another useful piece of propaganda is the installation and operation of Air Pollution Recording apparatus in schools as part of the normal curriculum. Perhaps someone in the audience with special experience in these matters might care to comment on the relative values of the different propaganda media for the benefit of those representatives of authorities still in an early experimental stage.

Table 22—The attitude of the Press

On the whole the Press appear to have accepted the necessity for Clean Air and surprisingly few authorities indicated that they had received criticism or antagonism from this quarter but there is no doubt as to the extent of organized opposition from interested bodies, particularly coal merchants in certain parts of the country; and the advertisement of the Coal Utilization Council eulogizing the benefits of " a nice coal fire " are quite inexplicable, particularly when it is published in the Press and displayed in Smoke Control Areas. Surely co-ordination by the Minister of these quasi-Government departments would obviate friction, or is there no control over the wastes of bureaucracy?

Table 24—Boiler Operators

Comment on this has been dealt with in the Industrial Session.

Table 25—Changes in Act

The overall response of local authorities as shown in this Table is very enlightening, indicating as it does that a fairly large number suggest that changes in the Act are necessary, but close scrutiny of the many comments shows that many of the problems are local and not generally applicable and many of the difficulties will cease to exist when co-operation between local authority and industry is achieved. Only one authority considered that the Act should be compulsory and not permissive—this was in relation to the black areas.

There is a fairly general comment that the routine procedure in establishing Smoke Control Areas is unnecessarily cumbrous and leads to delays. There are further suggestions that the delivery of unauthorised fuels in Smoke Control Areas should be prohibited, and that there is a fear of the lack of certainty of sufficient supplies in suitable quantities of solid smokeless fuels if extensive Smoke Control Areas are made. Another suggestion is that Smoke Control Orders should be made on all new development.

Many of the comments covered matters at present outside the Act.

Application of the Act to Scotland

The material submitted in relation to Scotland was analysed in tables comparable with those already discussed.

Generally the problems raised are fortunately of a technical and not a national character. Therefore the comments made above are equally relevant.

In making this very brief summary of the very voluminous material produced as a result of these questionnaires it is inevitable that discussion on points admittedly important may not have been included. I would hasten to add that this is due to shortness of the session and no wish to suppress discussion on any topic.

In conclusion I would add that the views expressed are my own and not necessarily those of the National Society for Clean Air.

PART TWO—THE INDUSTRIAL ASPECTS

By

*E. M. Birtwisle**

Introduction

WHILST the Clean Air Act provisions authorizing the formation of Smoke Control Areas may not have universal support, the position is quite different in relation to industrial smoke. The reaction of the man in the street (or more likely, the housewife) confronted with a cloud of smoke arising from a factory chimney is immediate—" There should be a law ' agin ' it."

Many have been the attempts to secure an effective penal code which would be compatible with industrial effort and the protection of public health. Many have been the disappointments that those who have paid lip service to clean air were reluctant to see controls imposed. Our generation should be proud that in our lifetime a measure such as the Clean Air Act, 1956, is being applied to the problem of atmospheric pollution.

It is inevitable that a country like ours, dependent on coal as its main source of power, should accept that the complete abolition of pollution will not be realized for many years, but it is cheering to note the recognition of the fact that the need to retain raw coal as the main source of industrial heat is no reason for the continuance of smoke. It cannot be said too often that smoke issuing from a chimney is money being thrown away. Smoke and inefficiency are great companions.

Work must go on and coal must be burned. The Act and Regulations are designed to impose sufficient control for the reasonable protection of public health without slowing down the wheels of industry, but the effectiveness of the operation of this legislation depends very largely on a close understanding by local authorities and industry of each other's problems.

It is not sufficient to rest on the theoretical efficiency of legislation and co-operation; the Society are to be congratulated on their decision to find out from local authorities by means of a detailed questionnaire exactly how effective the Clean Air Act really is. That it is effective is indicated by the returns but that many problems are being encountered is also obvious. It is hoped that by indicating the progress made encouragement will be given to those authorities not yet fully engaged in this work and that by discussing problems encountered to point the way to some of the solutions.

Table 2—Contraventions

It would be comforting to be able to take the figures for zero contraventions and to presume that of the 1,037 authorities returning the questionnaire one third were satisfied that no plants in their areas had exceeded the limits for dark smoke emission laid down in the Regulations. It must, however, be admitted that it is much more likely that the full implementation of the control envisaged by the Regulations has not yet been put into operation and that the figures are merely indicative of a need for much more work to be undertaken. Indeed, it is probable that even those authorities who have returned details of contraventions are very conscious that there must be many instances when the limits are exceeded without their knowledge.

A comparison of the figures of prosecutions with those of contraventions indicates a very restrained approach to the use of court action. Many local authorites quite rightly take the view that especially in the early years of this new legislation advisory work should be a particular feature of control, but some measure of warning is necessary to those industrialists who regularly contravene the requirements that constant contravention cannot go unheeded and that even the most reluctant of local authorities must eventually find themselves with no alternative but the prosecution of such offenders.

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Particularly in the districts of local authorities who are regulating domestic smoke emission by creating smoke control areas is the public likely to be very conscious of industrial shortcomings and reports by the public of smoky industrial chimneys must of necessity be treated very much more seriously than they may have been in the past.

Table 3—Prosecutions

Where prosecutions have been undertaken a very high proportion have been successful, indicating that local authorities have generally only proceeded to court action where they had very good grounds for complaint. The smallness of the penalties imposed must not be regarded as indicating a low measure of importance of the cases taken, but we hope merely shows a feeling on the part of the Justices that the institution of successful proceedings will in itself have a very salutary effect on the offenders without at this stage requiring the imposition of larger penalties. If it should be found that the penalties imposed have not been sufficient to bring the offenders into compliance with the Act's requirements, more severe penalties must obviously be pressed for.

From the information available the specified defences were rarely pleaded: only 16 cases are reported. In seven cases some failure of a furnace was made the defence and in nine cases the unsuitability of the fuel. If these figures are representative of the attitude of most fuel users when prosecuted under this Act it would appear that they are reasonably well satisfied that the fuel being delivered to them is not the cause of smoke emission.

In reply to supplementary questions put to certain local authorities the most frequently observed reason for contravention is careless or unskilled stoking indicating very clearly a great need for the proper training of those in whose hands so often rests the opportunity to allow plant to smoke or not to smoke.

The age of the plant in respect of which prosecutions were undertaken is interesting, 49 per cent. being between 20 and 40 years old and 20 per cent. over 50 years old. Managements cannot hope easily to keep within the law whilst using plant designed in the early part of the century when the aptness of the comment " where there's muck there's brass " was generally accepted.

Table 4—Amendment of Regulations

It is surprising that so many local authorities are so soon suggesting the amendment of the Dark Smoke (Permitted Period) Regulations and in view of the comparatively small scale on which the Regulations have already been implemented it appears that many of the suggestions for amendment are not based on difficulties found in fact, but on difficulties which are contemplated.

Any new legislation of the comprehensive nature of the Clean Air Act and its Regulations is bound to have critics who would have wished for some strengthening of a particular measure. Perhaps it is not always realized that these measures reflect what Parliament is prepared to grant and not always what might be felt to be administratively desirable.

The Regulations as they stand represent a method of estimating emission which for the first time is based on checkable fact. No longer should there be any opportunity for argument between steam engineer and Public Health Inspector as to whether or not smoke was " black " or " dark," for within the limits of human error in estimation the occupier of a factory can readily check for himself whether an offence is being committed.

The smoke alarms and recorders now

being fitted in increasing numbers should prove to be most useful allies to the inspecting officer, for if these instruments are correctly fitted and maintained there should be little opportunity of material difference between the officer's record of emission and the record available in the boilerhouse. Indeed, one can visualize these instruments gradually being accepted as replacing the need for a lot of chimney observations and the fact that they are available to produce a 24-hour record of smoke emissions should be a most useful control for both management and local authority. This points to the desirability of regulations being made requiring the installation of smoke density meters.

There appear to be those who interpret the Regulations as requiring long periods of observation: in the minds of some up to the eight hour period which is mentioned. In the case of most smoky chimneys the period of observation can be quite short when " dark " smoke is observed for a period of more than four minutes or " black " smoke for more than two minutes. Longer observations are only required for short bursts of smoke and with chimneys likely to be dealt with at this stage it would not need a long observation to build up a total of ten minutes of dark smoke. It should be appreciated that Regulation 4 limits are a part of the limits prescribed by Regulation 3 and not a separate Regulation.

It is not necessary to use the standard Ringelmann Chart for all observations. The Microringelmann or the Telesmoke type of instrument are quite effective for general use.

It is recommended that all authorities should make the maximum use of the Regulations as they stand and if necessary test their provisions in court before deciding that material amendments are required.

Table 5—Temporary Exemptions

On considering these figures it should be remembered that section 2 exemptions are only to cover a period of seven years from July 5th, 1956, so that more than four years of the period of exemption has already gone.

In general the exemptions have been granted in respect of out-of-date plant which will not be required on the installation of new machinery or for plant to be replaced in some long term re-equipment programme.

Some exemptions, however, have been granted on the grounds of insufficiency of time and money to re-equip. With less than three years for all the necessary work to be done it is appropriate to warn all concerned of the position.

Table 6—New Furnaces

It appears that most new plant is being installed so as to comply with the requirements of section 3. With the large scale advisory services now available to plant operators it would have been most disappointing if it had been found to be otherwise, but the questionnaire reveals striking figures of the number of occasions on which plant has been installed without notification of the installation being sent to the local authority. Few plants are installed these days without either architectural or engineering supervision and it is difficult to understand how these professional advisers can be ignorant of the requirements of the Act.

It may be, however, that a large proportion of the cases of failure to notify arise from the installation of plant by means of adaptation or replacement of existing equipment and under circumstances which were not thought to be in the nature of an installation envisaged in the wording of section 3. There is room for some argument on the rather vague wording of the section and the lack of a definition of " furnace," but as the mere notification of proposals is quite a harmless process one would always advise the principle of " if in doubt, notify." Some publicity on this point is obviously called for and local authorities are urged to make the receipt of notification an opportunity for a helpful discussion on the proposals. It is only by the building up of a widespread feeling that it is a good thing always to keep the local authority officers in the picture that effective progress will be made.

Table 7—Prior Approval

The prior approval arrangements seem to be reasonably attractive to those installing new plant and the indications are that the vast majority of applications have been given approval. One of the most satisfying aspects of Clean Air Act work is this further opportunity for close co-operation which is given in those cases where prior approval is asked for.

Of the cases refused many were in respect of proposals to use variable fuels such as refuse and wood waste in incinerators.

Concern was evident on the need for lagging steel chimneys of oil-fired plant. Blum, Lees and Rendle (1959), have published a most useful study of the smuts emerging from such plants and of effective means of prevention by lagging and shielding the steel stack.

Insufficient height of existing chimneys was in some cases the reason for rejection: difficulties under this heading are mentioned in the paragraph dealing with section 10 administration.

Table 8—Prior Approval Procedure

When the prior approval provisions were introduced there was a great deal of comment on the type of arrangement which would be necessary for advising local authorities and their officers on the approval of proposals. It appears that in general thoughts were running on the difficulties of dealing with plans which included complicated technical problems in regard to specialized plant. From the information contained in the replies to the questionnaire it appears that no great difficulties have arisen and, indeed, that very largely prior approval has been given on an examination of the proposals by local authority officers either alone or in some instances assisted by other persons. In only five cases have the services of a joint committee been sought.

This position probably arises from the increasingly wider use of standard plant and packaged installations which from the drawing board stage have been designed especially to meet the stringent requirements of section 3. Here some reference must be made to the very effective part being played by plant manufacturers in producing the apparatus which the fuel consumer needs to enable him not only to show a good return for his capital outlay but to be sure of keeping within the requirements of the clean air legislation.

Table 9—Grit and Dust

The control of grit and dust does not follow the pattern of smoke control. The estimation of emission and the detection of plant responsible is not always easy. The standards to be applied and the decision as to what are "practicable means" are not indicated in the Act.

It is evident that because of these and other reasons only the grosser cases of grit and dust emission are being dealt with and that much investigation and experiment still require to be done.

Those industrialists who are conscious of their responsibilities in this matter are worried at the absence of any clear indication as to how much they will be expected to do and what methods they should adopt for minimizing emissions.

Nonhebel (1960) has summarized a deal of the information available on grit control and given design engineers the information needed when designing plant. Local authorities need a simpler approach to the problem with a reasonably accurate method of measuring emission and an acceptable standard.

The Minister of Housing and Local Government has given no indication of his readiness to make Regulations under section 7 (2); he should be aware of the growing need for action.

Table 10—Height of Chimneys

Whilst the information on the table records an impressive number of plans considered in relation to the suitability of the height of chimneys, the full importance of this part of the questionnaire is only realized by considering the administrative problems to which local authorities have referred and their general comment on the requirements of this section.

Section 10 requires that, with the exception of London, where plans for buildings or extensions, other than plans of residences, shops or offices, are submitted for bye-law approval the plans shall be rejected unless the height of any proposed chimney shown on the plans is sufficient for clean air purposes. On the face of it this seems to be a simple and very effective means of control.

In fact, local authorities have experienced or contemplate experiencing considerable difficulties due to:

1. the difference of opinion between public health officers on the one hand with their views on minimum height at which exhaust gases can be discharged without causing nuisance and architects and planners on the other with their views as to the maximum height to which a chimney can be carried without offending what in the past has been regarded as good design;

2. difficulties of choosing from the tremendous mass of technical information available the most appropriate method of deciding on what height of chimney will be sufficient to prevent the smoke, grit, dust or gases from becoming prejudicial to health or a nuisance;

3. the fact that suitable chimney heights can be upset after an approved chimney has been erected if additional or larger plant is connected to the stack;

4. the exemption granted in the building bye-laws to buildings at mines, and in the Public Health Act, 1936, to schools, buildings of statutory undertakings and other buildings, so that plans of chimneys erected in connection with these buildings need not be submitted;

5. the absence of measures to deal with the existing chimneys whose height is insufficient to prevent the smoke, grit, dust or gases which are emitted from becoming prejudicial to health or a nuisance.

The position is one that calls for action to resolve these difficulties and the suggested action to meet each of these points is:

1. Planners and architects must be educated to a realization that maintenance of clean air is in itself good planning and that arrangements for the discharge of effluent gases at a height at which the likelihood of damage to buildings, equipment and persons is reasonably reduced are just as essential as arrangements for proper drainage, for the proper removal of refuse and for the proper disposal of other waste products arising from building. Public health officers must present a very forceful argument on this point and not allow section 10 to be bypassed in favour of artistic theory. It is interesting to note the wording of this section which makes it quite clear that if a project which includes a new chimney cannot be reconciled with clean air requirements then that project does not proceed and that even though planning consent may have been given bye-law approval must be withheld.

2. The Ministry of Housing and Local Government in their " Memorandum on Miscellaneous Provisions " make it quite clear that in their opinion the guidance on chimney heights to be found in Appendix VI of the Report of the Committee on Air Pollution (Cmd 9322) may well be followed when local authorities consider proposals. This theoretical basis of height fixing is to be supplemented by consideration of the three factors laid down in section 10. The formula suggested is not as involved as it at first appears and it certainly produces a figure on which decisions can be based with confidence. Williams (1959), has produced a ready reckoner, which considerably simplifies the calculations involved. The use of this formula calls for a decision on the maximum concentration of sulphur dioxide which is to be allowed at ground level. It is generally thought that in less polluted atmospheres a concentration of 0·3 to 0·35 parts per million might be acceptable but in polluted areas not more than 0·25 parts per million should be accepted.

In the case of large plants with a steam output of 33,000 lbs./hr. or more this method of calculation gives place to the rule of 120 feet chimney height or 2½ times the height of adjoining buildings whichever is the greater.

It should be realized that as the law stands this calculation is the local authority's last chance to secure an adequate height and the responsibility must not be taken lightly.

3. It is a pity that section 10 control, which is capable of making a most useful contribution to reducing pollution from exhaust gases generally, should not be followed by similar control over the installation of new, larger or additional plant fitted to an existing stack which it is not proposed to rebuild. A stack properly designed for the plant originally connected to it may well be overloaded by the new proposals but the opportunity of fixing a new chimney height is lost as no plan of the chimney is required. This is a matter which should be looked at again by our legislators with a view to providing control of chimney heights for all new installations.

4. The pattern of control provided by section 10 is applied only where plans are submitted for bye-law approval. No logical argument can be produced for relieving those proposing to erect chimneys at mines, or schools, or in connection with statutory undertakings, from a similar control of chimney height. It might well be that our local authority colleagues responsible for dealing with bye-law plans generally, would support us in an investigation as to whether under present day conditions exemption from bye-law control as a whole can logically be continued, but whether with their support or alone we are justified in asking that this matter should be reconsidered, or some new measure be written into this section so as to apply height control to all chimneys.

5. There comes a limit to the amount of control which can be made to apply to conditions obtaining at the time new legislation is introduced. Desirable as it might be to have wide powers to deal with existing chimneys which are too low it is unlikely that such powers could be easily written into the Clean Air Act. Technically it might well be impracticable to raise the height of a chimney without entire reconstruction of foundations and other major works, but if the loophole mentioned in paragraph 3 were closed, existing low chimneys would gradually be eliminated as new equipment is installed. In many cases of chimneys which are too low for the satisfactory dispersion of gases etc., as required by section 10, contravention of the Dark Smoke (Permitted Periods) Regulations will give the opportunity for pressure to be brought under section 1 for the installation of improved plant and in the necessary reconstruction to achieve an adequate chimney height.

Table 19—Smoke Nuisances

Smoke nuisances may relate to smoke from domestic premises other than from the house chimneys, smoke from the chimneys of commercial or industrial buildings other than "dark" smoke or smoke from burning materials in the open.

Nuisances from domestic premises are linked with Smoke Control Orders and dealt with in the paper on that work. Most other nuisances arise from the burning of waste material either in plant or in the open. Little statutory action has been taken by local authorities to deal with this matter.

The question which always arises is "Is burning the best method of disposal?" Every day vast quantities of household refuse made up of a great variety of material are successfully disposed of without burning. Is some extension of the local authority refuse collection service a better method than having a multiplicity of people trying often ineffectively to dispose of waste on their own works?

If circumstances are such that material must be burnt and the appliance used as a chimney, section 1 will control smoke which is "dark." Smoke which is not dark and which is a nuisance to the inhabitants of the neighbourhood is to be controlled by section 16 which also applies to smoke from material being burnt in the open. The nuisance provisions so well known to Public Health Inspectors and so well used in the past to deal with all manner of problems are to be used with certain adaptation. Reluctance to use these powers has perhaps been based on the lack of a suitable remedy but where prohibition of burning is not appropriate, apparatus capable of dealing effectively with the incineration of almost any type of material is now available.

Table 21—Publicity

Today there is surely no industrialist who is not aware of the Clean Air Act and its relation to his plant. For many years now some control has been exercised over smoke emission from his works and the attitude of many is to regard the new provisions as a logical extension of legislation. These new provisions are, however, unfortunately regarded by some as just another instance of the management being pushed around by local authority officers.

Whilst extensive publicity on the industrial provisions may not be as necessary as in the case of smoke control area work, the importance of constant contact with plant operators cannot be over emphasized; that many authorities realize this is evident from the returns, but much more remains to be done. It will be useful to have further comment on this important feature of our work.

Associations representing various industrial interests have displayed a welcome anxiety to keep their members informed of the Act's requirements and have held meetings and conferences at which the problems created have been discussed.

Table 24—Boiler Operators

With the generally accepted need for trained boiler operatives it is remarkable that although only 40 per cent. of the authorities reporting had courses available only a further 6 per cent. indicate the need for courses to be arranged in their areas.

The Society's policy is to secure the compulsory training of all stokers and it is hoped eventually to sponsor a Bill in Parliament to this end in the belief that a well trained stoker is the key to the proper use of fuel and the attainment of a clean atmosphere. If 100 per cent. trained staff is to be secured increased training facilities will obviously be needed on a very large scale.

Conclusion

It is not possible to summarize the detailed information shown in the tables but in general the returns indicate that a reasonable attempt is being made by many authorities and their officers to implement the industrial provisions of the Clean Air Act, 1956. The gradual extension of this work over the next few years will require a major contribution from fuel users, fuel suppliers, manufacturers of plant and local authorities, and a tremendous field for co-operation exists. It must not, however, be thought of purely as an exercise in co-operative effort; so far as local authorities are concerned the work involves the administration of a statute and those who fail to show a reasonable degree of compliance with the requirements expose themselves to the full rigour of the law.

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TABLES ON THE QUESTIONNAIRE REPLIES

TABLE 1

Proportion of Questionnaire Forms Returned

Type of Authority	*Total No. of Authorities*	*Returns*	
		No.	*Percentage*
England and Wales			
County Borough	83	80	95
Borough	318	234	73
Metropolitan Borough	29	29	100
Urban District	564	395	70
Rural District	474	222	47
Total	1,468	960	66
Scotland			
County Council	33	19	58
* Large Burgh	24	22	92
Small Burgh	174	52	23
Total	231	93	40

* Includes four Counties of Cities

TABLE 2

Table showing contraventions and prosecutions under Section 1 of the Clean Air Act, (Prohibition of Dark Smoke)

Key: Figures in ordinary type show the number of authorities observing number of contraventions in each group. Figures in **bold** type show number of prosecutions and figures in *italics* show the number of authorities prosecuting. Example: 30–**18**–*3* indicates that 30 authorities observed between 1 and 20 contraventions, and that 18 prosecutions in all were undertaken by 3 authorities

(a) *England and Wales*

No. of Contraventions	*No. of Authorities observing the No. of Contraventions in first column*					
	County B's	*Boroughs*	*Met. B's*	*U.D.'s*	*R.D.'s*	*Total*
Zero	3	73	5	167	136	384
1— 20	30– **18**– *3*	115–**3**–*3*	16–**2**–*2*	187–**5**–*3*	80–**0**–*0*	428– **28**–*11*
21— 60	22– **12**– *5*	35–**5**–*3*	3–**0**–*0*	36–**1**–*1*	6–**0**–*0*	102– **18**– *9*
61—100	11– **9**– *5*	7–**1**–*1*	4–**0**–*0*	4–**0**–*0*	0–**0**–*0*	26– **10**– *6*
101—250	10– **53**– *4*	4–**0**–*0*	1–**0**–*0*	1–**0**–*0*	0–**0**–*0*	16– **53**– *4*
251—500	1– **0**– *0*	0–**0**–*0*	0–**0**–*0*	0–**0**–*0*	0–**0**–*0*	1– **0**– *0*
Over 500	3– **31**– *2*	0–**0**–*0*	0–**0**–*0*	0–**0**–*0*	0–**0**–*0*	3– **31**– *2*
Totals	77–**123**–*19*	161–**9**–*7*	24–**2**–*2*	228–**6**–*4*	86–**0**–*0*	576–**140**–*32*
Total Contraventions	6,583	3,112	810	2,642	551	13,698

(b) *Scotland*

No. of Contraventions	*No. of Authorities observing the No. of Contraventions in first column*			
	Cty. Councils	*Large Burghs*	*Small Burghs*	*Total*
Zero	11	2	36	49
1— 20	5–**0**–*0*	10–**0**–*0*	14–**0**–*0*	29–**0**–*0*
21— 60	2–**0**–*0*	7–**1**–*1*	2–**0**–*0*	11–**1**–*1*
61—100	1–**0**–*0*	2–**0**–*0*	0–**0**–*0*	3–**0**–*0*
101—250	0–**0**–*0*	0–**0**–*0*	0–**0**–*0*	0–**0**–*0*
251—500	0–**0**–*0*	0–**0**–*0*	0–**0**–*0*	0–**0**–*0*
Over 500	0–**0**–*0*	1–**0**–*0*	0–**0**–*0*	1–**0**–*0*
Totals	8–**0**–*0*	20–**1**–*1*	16–**0**–*0*	44–**1**–*1*
Total Contraventions	137	1,026	152	1,315

TABLE 3
Prosecutions

Penalties imposed when prosecution has been undertaken

England and Wales *Fine*	*County Boroughs*	*Other Local Authorities*	*Total*
£1-10	88	9	97
£11–20	13	0	13
£21–50	2	1	3
Over £50	0	0	0
Guilty, no fine	8	0	8
Totals	111	10	121
Cases dismissed	6	6	12
No information	6	1	7

Scotland

In the one case in which a prosecution took place in Scotland (a large Burgh) a fine of less than £10 was imposed.

TABLE 3b
Number of plants employing workers as specified in first column, proceedings having been taken under Section 1 of the Act

Type of Authority	*Number of Workers*			
	Less than 50	51—499	500—1,499	*Over* 1,500
England and Wales				
County Boroughs	37	50	15	8
Boroughs	2	5	0	0
Metropolitan Boroughs	1	2	0	0
Urban Districts	2	2	0	0
Scotland				
Large Burghs	1	0	0	0

Note: There were no proceedings taken in Rural Districts, County Councils and Small Burghs

TABLE 3c

Number of installations grouped by age of plant

Age of Plant	*England and Wales*	*Scotland*
Less than 5 years	5	—
5—20 years	27	1
20—40 years	55	—
40—50 years	11	—
Over 50 years	21	—
Totals	119	1

TABLE 3d

Types of installation on which offences under Section 1 were committed

Type of Plant	*England and Wales*	*Scotland*
Lancashire Boilers	66	—
Vertical Boilers	12	1
Section Boiler with Underfeed Stoker	3	—
Trade Refuse Disposal Plant	3	—
Miscellaneous	20	—
Totals	104	1

TABLE 3e

Reasons for the Contraventions

Careless or unskilled stoking	23
Overloading	8
Bad firing	3
Unsuitable fuel	5
Poor maintenance	6
Age of boiler	2
Unsuitable or underloaded boiler	7
Lack of supervision	3
Burning out of paint drums placed in Furnace Chamber	1

TABLE 4

Amendment of Dark Smoke Regulations

Type of Authority	*No. of Authorities* *Proposing amendment*	 *Recommending no amendment*	 *Making no comment*	*Percentage of total Authorities replying and proposing amendment*
England and Wales				
County Boroughs	28	48	4	35
Boroughs	52	144	38	22
Met. Boroughs	7	17	5	24
Urban Districts	60	255	80	15
Rural Districts	10	212 *		4
Total	157	803		16
Scotland				
County Councils	0	16	3	0
Large Burghs	6	16	0	27
Small Burghs	1	30	21	2
Total	7	62	24	8

* This includes a few Rural Districts who recommended no amendment—the very large majority made no comment

TABLE 5

Temporary Exemption under Section 2 of the Act—number of authorities receiving requests, and number of authorities granting exemptions

England, Wales and Scotland combined

Number of Requests	*Number of authorities* *Receiving Requests*	 *Granting Requests*
1— 5	99	72
6—10	8	8
11—50	3	2
Over 50	1	1
Total	111	83

TABLE 6

Installation of New Furnaces

(Section 3)

England, Wales and Scotland combined

Number of contraventions	22
Number of cases of failure to notify	343

TABLE 7

Number of authorities receiving requests for Prior Approval under Section 3 of the Act

Number of Requests	*Total number of authorities receiving Requests*	
	England and Wales	*Scotland*
Zero	559	63
1— 10	349	24
11— 20	32	4
21— 50	14	0
51—100	4	0
Over 100	2	2
Total number of authorities	401	30
Total number of requests	2,455	345
Not proceeded with	94	7
Number of requests refused	23	2

TABLE 8

Methods of Examination of Prior Approval requests, showing number of authorities and percentages (in brackets)

Type of Authority	*(a) Solely by Authority's Officers*	*(b) Officers assisted by other persons, joint committees, etc.*
England and Wales		
County Borough	60(81)	14(19)
Borough	101(69)	47(31)
Metropolitan Borough	17(63)	10(37)
Urban District	73(53)	65(47)
Rural District	50(68)	23(32)
Scotland		
County Council	9(69)	4(31)
Large Burgh	9(56)	7(44)
Small Burgh	10(71)	4(29)

TABLE 9

Contraventions reported under Sections 5 and 6 of the Act, (Grit and Dust)

Number of known contraventions	*Number of authorities observing contraventions as specified in first column*	
	England and Wales	*Scotland*
1— 10	127	13
11— 50	7	3
51—200	1	0
Over 200	1	0
Total number of authorities	136	16
Total number of known contraventions	931	81
Total number of prior approvals	59	6

TABLE 10

Number of plans received relating to the height of chimneys classified by types of authority

(*a*) *England and Wales*

Number of plans received	*Cty B's*	*Boro's*	*U.D.'s*	*R.D.'s*	*Total*
1— 10	32	98	124	41	295
11— 50	24	16	7	1	48
51—100	5	1	0	0	6
101—150	3	0	0	0	3
Over 150	2	0	0	0	2
Total authorities	66	115	131	42	354
Total plans	1,918	753	436	108	3,215
Number of plans accepted *without* amendment	1,318	497	262	90	2,167
Number of plans accepted *after* amendment	554	241	151	18	964
Number of plans *refused*	46	15	23	0	84
Number of authorities with administrative problems or comment	44	68	47	9	168

Note: Metropolitan Boroughs are not listed, as the London County Council is responsible for this aspect of Town Planning

(*b*) *Scotland*

Number of plans received	*Cty C's*	*Large Burghs*	*Small Burghs*	*Total*
1—10	3	11	9	23
11—50	2	5	0	7
Over 50	1	0	0	1
Total authorities	6	16	9	31
Total plans	109	144	13	266
Number of plans accepted *without* amendment	106	95	9	210
Number of plans accepted *after* amendment	3	47	4	54
Number of plans *refused*	0	2	0	2
Number of authorities with administrative problems or comment	3	9	2	14

TABLE 11

Number of Smoke Control Areas classified by types of authority

Type of Authority	*Number of areas by 1/7/60*						*Total auth. with areas*	*Total areas*
	1	2	3	4	5	*Over* 5		
Cty Borough	13	6	1	2	1	1	24	50
Borough	10	0	0	0	0	1	11	19
Metropolitan Borough	10	5	1	1	0	0	17	27
Urban District	10	2	1	0	0	4	17	47
Large Burghs (Scotland)	4	0	0	0	0	1	5	15
Totals	47	13	3	3	1	7	74	158

Note: There were no Smoke Control Areas in Rural Districts, County Councils and Small Burghs

TABLE 12

Number of Conversions required in Smoke Control Areas, classified by type of authority and number of premises in the Area

Premises in Areas	*England and Wales*								*Scotland*		*Totals*	
	County Boroughs		*Boroughs*		*Met. Boroughs*		*Urban Dis'ts.*		*Large Burghs*			
	Auths.	*Convs.*	*Auths.*	*Convs.*	*Auths.*	*Convs.*	*Auths.*	*Convs.*	*Auths.*	*Convs.*	*Auths.*	*Convs.*
Less than 50	0	0	1	0	0	0	0	0	0	0	1	0
51— 100	2	135	0	0	0	0	3	0	1	40	6	175
101— 500	9	1,168	3	522	5	397	6	446	2	437	25	2,970
501—1,000	8	2,244	7	1,535	1	330	3	945	0	0	19	5,054
1,001—5,000	4	3,895	0	0	8	5,949	5	539	2	1,007	19	11,390
Over 5,000	1	6,700	0	0	3	4,216	0	0	0	0	4	10,916
Totals	24	14,142	11	2,057	17	10,892	17	1,930	5	1,484	74	30,505
Total premises	17,551		6,622		45,128		16,457		3,096		88,854	

Note: There were no Smoke Control Areas in Rural Districts, County Councils and Small Burghs

TABLE 13

Arrangements for Smoke Control Area survey staff made by different types of authority

Type of Authority	*Public Health Inspectors*	*Special Staff*	*Surveyors Department*	**Other Methods*
England and Wales				
Cty Borough	45	12	0	2
Borough	72	7	1	3
Metropolitan Borough	23	16	0	2
Urban District	106	10	6	0
Rural District	29	1	1	0
Scotland				
Cty Council	5	0	0	0
Large Burgh	8	2	0	1
Small Burgh	6	0	4	1

* These include the use of " Administrative Staff " and Students

TABLE 14

Number of Authorities with Smoke Control Areas recording difficulty over Miner's Concessionary Coal, classified by types of authority

Type of Authority	*Number of authorities recording difficulty*
England and Wales	
Cty Borough	4
Borough	8
Urban District	45
Rural District	8
Scotland	
City Council	0
Large Burgh	0
Small Burgh	4

Note: 36 other authorities recorded the presence of other difficulties

TABLE 15

Public Opinion in Smoke Control Areas

Type of Authority	*Very Favourable*	*Favourable*	*Non-Committal*	*Critical*	*Strongly Critical*	*No Answer*
England and Wales						
Cty Borough	0	14	6	3	0	1
Borough	3	6	2	0	0	0
Metropolitan Borough	1	15	1	0	0	0
Urban District	1	9	2	2	0	3
Scotland						
Large Burgh	0	2	1	1	0	1

Note: There were no Smoke Control Areas in Rural Districts, County Councils and Small Burghs

TABLE 16

Number of Authorities using Gas Ignition in Smoke Control Areas

	England and Wales	*Scotland*
Yes	31	3
No/No comment	38	2

TABLE 17

Smoke Control Areas—Special Exemptions

Number of Special Exemptions	*England and Wales*	*Scotland*
Less than 50	17	2
51—100	0	0
Over 100	4	0

TABLE 18

Smoke Control Areas—Contraventions

Type of Authority	*Total Contraventions*	*Prosecutions*
England and Wales		
County Boroughs	524	21
Boroughs	12	0
Metropolitan Boroughs	110	1
Urban Districts	128	2
Scotland		
Large Burghs	61	0
Totals	835	24

There were no contraventions in Rural Districts, County Councils and Small Burghs

TABLE 19

Smoke Nuisances

England, Wales and Scotland combined

Prosecutions	9
Successful	8
Comments on Industrial Waste	146
Comments on Garden Refuse Fires	60

TABLE 20

Number of authorities adopting the Building Bye-law and percentage (in brackets) of those returning the Questionnaire

Type of Authority	*Number Adopted*
England and Wales	
County Boroughs	69(86)
Boroughs	153(64)
Urban Districts	240(61)
Rural Districts	48(22)
Scotland	
County Councils	6(32)
Large Burghs	17(77)
Small Burghs	10(19)
Totals	543(56)

Notes: We are informed that the L.C.C. has made a bye-law similar to the Building Bye-law, applicable to the Metropolitan Area.

The latest information from the Ministry of Housing and Local Government is that in England and Wales, 601 authorities have now had the Bye-law confirmed by the Minister

TABLE 21

Publicity undertaken by authorities and other bodies, classified by type of authority

Type of Authority	*Number of Authorities (percentages in brackets)*					
	In Industry		*General Smoke Problem*		*Smoke Control Areas*	
	By Auth.	*By another body*	*By Auth.*	*By another body*	*By Auth.*	*By another body*
England and Wales						
County Boroughs	43(54)	16(20)	53(66)	39(49)	49(61)	31(39)
Boroughs	65(28)	25(11)	86(37)	34(15)	77(33)	31(13)
Metropolitan Boroughs	11(38)	1(3)	20(69)	5(17)	26(90)	10(34)
Urban Districts	58(15)	16(4)	101(26)	3(1)	77(20)	28(7)
Rural Districts	15(7)	9(4)	12(5)	7(3)	4(2)	3(1)
Scotland						
County Councils	1(5)	2(10)	3(16)	0(0)	1(5)	0(0)
Large Burghs	16(73)	6(27)	17(77)	7(32)	16(73)	7(32)
Small Burghs	5(10)	3(6)	4(8)	1(2)	4(8)	3(6)

TABLE 22

General attitude of Press toward Clean Air Policy

Type of Authority	*Enthusiastic*	*Favourable*	*Non-committal*	*Critical*	*Antagonistic*	*No answer*
England and Wales						
County Boroughs	11	52	8	1	0	7
Boroughs	6	104	58	0	0	45
Metropolitan Boroughs	0	25	4	0	0	0
Urban Districts	7	123	151	1	4	99
Rural Districts	6	33	68	0	0	107
Scotland						
County Councils	1	5	2	0	0	11
Large Burghs	2	15	4	0	0	1
Small Burghs	1	7	18	0	0	26
Totals	34	364	313	2	4	296

TABLE 23

Organized opposition to the Act or Clean Air Policy

Type of Authority	*Number of Authorities reporting*
England and Wales	
County Boroughs	16
Boroughs	22
Metropolitan Boroughs	1
Urban Districts	41
Rural Districts	7
Scotland	
County Councils	1
Large Burghs	3
Small Burghs	2

TABLE 24

Boiler Operators

	Number of Authorities	
	England and Wales	*Scotland*
Courses available	371	36
Need for courses	57	5
Support likely from:		
Employers	45	4
Operators	30	3

TABLE 25

Number of authorities commenting on the desirability of changes in the Act

Type of Authority	*Satisfactory*	*Change*
England and Wales		
County Boroughs	9	28
Boroughs	23	48
Metropolitan Boroughs	5	9
Urban Districts	21	49
Rural Districts	4	9
Scotland		
County Councils	1	2
Large Burghs	2	6
Small Burghs	2	1

APPENDIX: THE QUESTIONNAIRE

The substance of the questionnaire on which the foregoing reports are based is reproduced below for reference. The spaces, and in some cases boxes, for replies are omitted. Except in Question G it was asked that the figures given should relate to the first three years of the working of the Act, i.e. *to 31st December, 1959.*

A: Section 1—Prohibition of Dark Smoke

(i) Number of contraventions observed
(ii) Number of contraventions dealt with by (*a*) informal action
  (*b*) prosecution
(iii) Number of penalties imposed within following categories:
  Fine (*a*) £1-10; (*b*) £11-20; (*c*) £21-50; (*d*) Over £50; (*e*) Cases found guilty, but dealt with other than by fine
(iv) Frequency of use of specified defences: (*a*) Lighting up; (*b*) Failure of furnace; (*c*) Unsuitable fuel; (*d*) Combinations of these three defences
(v) Number of Cases dismissed
(vi) (*a*) Do you consider the Dark Smoke (Permitted Periods) Regulations require amendment? (Yes/No)
  (*b*) If so, why?
(vii) Any further information or comment

B: Section 2—Temporary Exemptions

(i) Number of exemptions requested
(ii) Number granted
(iii) Principal reasons for requests
(iv) Any further information or comment

C: Section 3—New Furnaces

(i) Number of contraventions under sub-section (i)
(ii) Number of known cases of failure to notify intention to install
(iii) Further information or comment

D: Section 3—Prior Approval

(i) Number of requests for prior approval
(ii) Number of applications not proceeded with
(iii) Number of requests refused
(iv) How are prior approval requests examined?:
  (*a*) By authority's officers (Yes/No); (*b*) By officers in consultation with other persons (Yes/No); (*c*) By Joint Committee of local authorities (Yes/No); (*d*) By other special body (Yes/No)
  If by (*c*) or (*d*), please give further details

E: Sections 5 and 6—Grit and Dust

(i) Number of known contraventions falling within the province of the local authority
(ii) Number of prior approval submissions under S.6(1)
(iii) Further information or comment

F: Section 10—Height of Chimneys

(i) Number of plans (*a*) submitted; (*b*) rejected; (*c*) accepted without amendment; (*d*) amended after informal discussion
(ii) General procedure involved, and administrative problems encountered

G: Section 11—Smoke Control Areas

(i) (*a*) Has the Authority any Areas in operation (or will have on or before 1st July, 1960) (Yes/No)
  (*b*) If "Yes", please give number of areas
  (*c*) Total number of domestic premises. Total conversions effected
  (*d*) By whom is survey and other detailed work carried out when an area is planned (*e.g.* Public Health Inspectors, Special Staff, Surveyor's Dept. etc.)
  (*e*) Have difficulties over miners' concessionary coal been a deterrent to local authority action: (Yes/No/Not applicable)
(ii) Where Areas are in operation:
  (*a*) What difficulties (if any) have arisen?
  (*b*) Have they been overcome? (Yes/No) If not, please specify
  (*c*) The prevailing public opinion in the areas is: (Very Favourable/Favourable/Non-Committal/Critical/Strongly Critical)
  (*d*) Do you insist on gas ignition for solid fuel fires? (Yes/No)
  (*e*) Please give figures and particulars of special exemptions of individual installations, etc.
  (*f*) Number of contraventions of S.11 (1) observed; (2) Dealt with by informal action; (3) Dealt with by prosecution
(iii) Further information or comment

(*N.B.*—If your Authority has introduced a Smokeless Zone under a Private Act, tenancy agreement, etc., please do not include in above returns. Information would be appreciated on a separate sheet)

H: Section 16—Smoke Nuisances

(i) (*a*) Number of prosecutions under S.16; (*b*) Number successful
(ii) Principal causes of such nuisances
(iii) Any particular information about the burning of industrial wastes
(iv) (*a*) Do you make special arrangements for disposal of garden refuse? (Yes/No)
(*b*) If so, please give particulars
(v) Further comments

J: Section 24—Building Bye-law

(i) Has your Authority adopted this Bye-law? (Yes/No)
(ii) If so, have you any observations on its working—administration, difficulties, etc.

K: Publicity, Educational Work, etc.

(i) Is publicity or educational work relating to the Act being undertaken in industrial concerns:
(*a*) by the Local Authority? (Yes/No);
(*b*) by another body? (Yes/No);
If so, please give brief details
(ii) Is publicity or educational work being undertaken relating to:
(*a*) the general domestic smoke problem? (By local authority Yes/No, by other body Yes/No); (*b*) smoke control areas? (By local authority Yes/No; by other body Yes/No)
If so, please give details (including extent of work)
(iii) General attitude of the Press towards clean air: (Enthusiastic/Favourable/Non-Committal/Critical/Antagonistic)
(iv) Is there any organized (*a*) opposition to the Act? (Yes/No); (*b*) denigration of Clean Air Policy? (Yes/No)
If so, please give brief details
(v) Further information or comment

M: Boiler Operators

(i) Are there courses for the training of Boiler Operators in, or conveniently near to your area? (Yes/No)
(ii) If not, is there a need for such courses? (Yes/No)
(iii) Do you think support would be likely from (*a*) employers? (Yes/No)
(*b*) operators? (Yes/No)
(iv) Can you give information on (*a*) the number of boiler operators employed within local authority's area; (*b*) the proportion working on hand-fired boilers?
(v) Further information or comment

N: General

Any general observations on the working and value of the Act
Suggestions for changes in the Act

SUPPLEMENTARY QUESTIONNAIRE ON PROSECUTIONS UNDER SECTION I AND ON PRIOR APPROVAL

Section I

Where prosecutions have taken place, will you you please indicate:

(i) Number of workers in whole plant.*
Less than 50, 50-499, 500-1,499, over 1,500.
(*" Plant " here means the whole factory, or factories, in which the boiler or furnace is installed, or which are served by it.
Where more than one prosecution has been undertaken, please show total number of plants in EACH group).
(ii) How frequently were the " specified defences " used? (See Section 1(3) of the Clean Air Act).
(*a*) Lighting up, (*b*) Failure of furnace, (*c*) Unsuitable fuel, (*d*) Combinations of these three defences.
(iii) On what type of installation was the offence committed? (e.g. Water Tube Boiler, Package Boiler, etc.).
(iv) Capacity of installation (in B.T.U.s).
(v) Have you any idea of the age(s) of the installation(s)?
Less than 5 years, 5-20 years, 20-40 years.
(Where more than one prosecution has been undertaken, please show total number of plants in each age group).
(vi) Can you state what, in your view, was the *reason* for the contravention(s)? (e.g. overloading of boiler, age of boiler, unskilled or careless stoking, etc.).

Section III

Where requests for Prior Approval under this Section have been *refused* please can you give any information about the principal reasons for refusal.

ADDITIONAL REPORT FOR SESSIONS ON THE WORKING OF THE CLEAN AIR ACT

Questionnaire to Port Health Authorities on Section 20

IN Great Britain there are 58 Port Health Authorities responsible for those aspects of public health administration applicable to ships using the port. Section 20 of the Clean Air Act and the Dark Smoke (Permitted Periods) (Vessels) Regulations vest in these Authorities the responsibility for the implementation of the Act within the port, or within the estuary controlled by the Authority.

In order to ascertain the experience of the Port Health Authorities during the first three years of the working of the Act, a slightly modified form of questionnaire was sent to each Authority, of which 49 (84 per cent) were returned.

Prohibition of Dark Smoke under Section 1

Number of contraventions

Of the 49 Authorities returning the Questionnaire, 22 indicated that they had observed no contraventions, two reported more than 100 but less than 250 contraventions of Section 1, while one Authority reported between 500 and 1,000 contraventions (see Table 1). Over 71 per cent (1,297) of the contraventions were reported by four Authorities.

In few cases was the matter dealt with by prosecution. Four Authorities instituted proceedings in a total of 17 cases, as a result of which 19 defendants were fined and one given an absolute discharge (Tables 2 and 3). The case against one defendant was dismissed. Many of the Authorities are responsible for small ports, used mainly by small motor vessels, but in the case of the larger ports, there seem to be several reasons for the small number of legal proceedings instituted. Several Authorities reported that a policy of education, with prompt approaches to the Engineer Officer or the Master of the vessel when necessary, had resulted in a fair degree of improvement. Prosecution would obviously be used only as a last resort. Some of the major Authorities have been hampered by practical difficulties in the application of the Regulations. In one case, a large port reporting 867 contraventions stated that the Regulations were so difficult to implement that prosecution had been possible in only six instances. The Regulations permit a vessel with hand fired boilers burning coal to emit an aggregate of 20 minutes dark smoke in any one hour, when under way. Especially when emissions of dark smoke are intermittent, a vessel must be kept under observation over a considerable period of time, and unless a launch is being used for observation purposes, such supervision is difficult. Moreover, an offender can pass out of the area of jurisdiction of the Port Health Authority before the 20 minute period has elapsed, and prosecution is then not possible.

Comments from several large ports suggest that the main offenders are tugs, dredgers, hoppers, and harbour craft, and some old, coal-burning merchant ships.

Penalties imposed

Of the 20 defendants convicted of an offence, 12 were fined less than £10, and it may be that magistrates tend, at this stage, to take a lenient view, but the number of prosecutions reported is so small that any conclusions drawn might well be misleading.

No information is available about the defences used where prosecutions took place.

Amendment of the Dark Smoke (Permitted Periods) (Vessels) Regulations

Most Authorities indicated their views on the desirability of amending the Regulations, six making no comment, sixteen proposing amendment, and twenty-seven proposing no amendment. In Table 4 the experience (in terms of contraventions) of these two last groups is compared. It will be apparent that, not only have the Authorities proposing amendment to the Regulations had more experience of observing contraventions (a total of 1,429 compared with 379), but that twelve of the sixteen Authorities reporting more than 10 contraventions are in favour of amendment. Moreover, the return from one Authority recommending " no change " reports 212 contraventions, representing 56 per cent of the total returns in this category, and in this case (a port and canal town) there are geographical and navigational problems which require special consideration.

With one exception, where an amendment has been proposed by an Authority, it includes a recommendation that the permitted periods be shortened. Some Authorities also propose shortening the observation period, on the grounds mentioned above—that it is difficult to keep a vessel under observation for periods of one or two hours unless suitable launches and adequate staff are available.

Temporary Exemptions

The forms returned show that the Authorities replying had received no applications for temporary exemptions, under Section 2 of the Act.

Other Comment

By sub-section 5 of Section 3 of the Act, the application of permissive " prior approval " is limited to new boiler plant attached to already existing buildings, or to boiler plant " for the time being fixed to or installed on any land." One interesting proposal is that in the case of new British vessels, a form of " prior approval " of boilers before installation should be introduced. The regulations might also provide for the fitting of smoke meters and other instruments to assist boiler operators to control smoke emission.

Another proposal is that a periodic survey of marine boiler plant be undertaken, to ensure that boilers are capable of providing adequate steam without forcing. Since many contraventions are caused by the overloading of boilers, a regular survey of this kind would do much to reduce smoke emissions. Unfortunately, it is likely to tax unduly the available resources of skilled personnel, and on this ground may prove impracticable.

Table No. 1

Number of contraventions observed under Section 1 of the Act

Number of contraventions	*Number of authorities observing contraventions in first column*
0	22
1–20	15
21–60	7
61–100	2
101–250	2
500–1,000	1
Total number of authorities	49
Total number of contraventions	1,808

NOTE: Only four authorities instituted prosecutions. In no case did the number of prosecutions exceed 10.

Table No. 2

Number of prosecutions, etc.

Number of authorities which prosecuted	4
Number of cases taken	17
Number of defendants	21

Table No. 3

Penalties imposed in the event of prosecution

Penalty	*Number of defendants*
£1–£10	12
£11–£20	2
£21–£50	5
Absolute discharge	1
Case dismissed	1
	21

Table No. 4

Amendment of the Dark Smoke (Permitted Periods) (Vessels) Regulations

Number of contraventions reported	*Number of authorities proposing that the regulations be changed*	*be not changed*	*Total number of authorities*
0	1	15*	16
1–10	3	8	11
11–50	7	2	9
51–100	3	1	4
101–250	1	1	2
251–1,000	1	0	1
Total authorities	16	27	43
Total contraventions	1,429	379	1,808

* A further six authorities observed no contraventions and made no comment about amendment.

Discussion (Thursday afternoon)

Alderman Mrs. A. E. Prendergast, in opening the discussion said the questionnaire indicated the number of conversions required at the time of the survey; although there might not be a single objection only about one half or less of these conversions were carried out. Apart from wondering what happened at these premises their publicity campaigns were not apparently effectively reaching the people. In Dagenham in dealing with a second area of nearly 4,000 council houses it was hoped to use for demonstration purposes for, say, one day, houses as and when they became vacant in a number of different streets. It was hoped, in fact, to bring the publicity to the people in their own streets.

Dr. J. S. G. Burnett, (Preston), drew attention to the effect, on the general population of a town, of publicity designed to acquaint residents in projected smoke control areas with the intentions behind the legislation. It was common at meetings and exhibitions to meet householders from all over the town intimating their active support for clean air and asking whether they could receive grant towards conversion although their property, solely because of administrative difficulties, was not situated in an area designated for immediate control. These people were active supporters of the clean air movement, they lived in " black areas " and were denied immediate financial help whereas many of the " couldn't care less type " benefited by the lucky chance of living in a district chosen for immediate action. He felt that the Minister of Housing and Local Government and his staff were actively in support of clean air but their actions were governed by existing statutory legislation. It was for those working at the periphery and in close contact with problems such as these to put forward suggestions that might be of help to the Minister. The Society might consider a fresh approach to the Minister based on the idea that where an authority proposed to proceed with smoke control orders within the following five years all householders within such designated areas could receive grant for approved conversions conditionally on their agreeing not to emit smoke from a chimney of their house.

It was logical to help rather than to punish supporters and failure to meet what was a sound request based on good commonsense solely because of " administrative reasons " was an excellent way of alienating the sympathies of the thinking section of the population.

S. Cayton, (West Bromwich), said he thought there was need for procedural improvements leading more quickly to smoke control orders. He thought local authorities and the Ministry had enough experience and knowledge to enable them to estimate the total cost with reasonable accuracy without the necessity of visiting every house. This could be left until the Order was confirmed and a date fixed for its operation.

If areas were made much larger say, up to five years' work and divided into annual portions for operational purposes, any householder could be paid grant after confirmation of the whole area even though in a particular case he might be acting five years before the latest date. This change would produce a more positive approach and enable the public to know the programme well in advance and *take advantage* of it if they so desired.

C. H. Crawford, (Brierley Hill), emphasized that the Society was concerned with progress in smoke control areas directed primarily at domestic premises.

The greatest obstacle to progress was the cumbersome administrative procedure illustrated by the length of time which elapsed between approval in principle and the operation of an order. It would be easier if:

(1) The five-year programme was approved and local authorities given authority to proceed with orders necessary.

(2) All orders affecting new housing estates came into force without the six months waiting period.

(3) A system of standard grants for adaptations was adopted similar to the standard improvement grant system.

Alderman W. L. Dingley, (Warwickshire County Council), said that 80 per cent. of smoke nuisance was caused by domestic chimneys, the Minister of Education should consider introducing clean air as a priority subject on school curricula. To kill old people with air pollution was not cultural advancement.

He was glad to be able to say that Warwickshire Clean Air Council had arranged to meet headmasters or their representatives and it was hoped to be able to arrange education on clean air to be given in the schools.

His second point was that in single storey buildings with short flues, and when normal convection was inadequate he thought there was a case for the development of built-in electrical fractional horse power motor blowers.

P. H. G. Grimmett, (Wednesfield), commenting on his experiences in the operation of smoke control areas mentioned the difficulty which arose in his authority in regard to the implementation of the Smoke Control Order dated to come into operation on 1st May 1960 but which, due to overtures and as the result of a meeting with the fuel distributors of the area, was deferred from so coming into operation for one month for the very simple reason that the original date of operation coincided with the coming into force of summer prices of fuel, and the submission of the fuel distributors that they would need to buy at winter prices to sell at summer prices with a consequent loss. With some apprehension the deferment was agreed and conference was advised that no difficulties arose as a result of this decision from either persons affected or fuel distributors, but that such operational dates should be avoided.

Referring to firelighting difficulties, Mr. Grimmett suggested that the normal straight insertion poker was not a good type for such firelighting and that the Nicor or Intregal burner was the better adaptable for lighting fires from the simple scientific fact that the bars of the fire appliance would also be partially heated and that primary air following thereafter into the fuel bed was pre-heated to continue the combustion of the fire. In fact experiences had been that 40 minutes firing had been required by some householders in smoke control areas, which had been cut to seven or eight minutes with use of the under firebar poker; and personally lighting a number of fires on the area had adequately proved this point to occupants of dwellings. Reference was also made to a previous comment of a saving in fuel bills as the result of using smokeless fuel and confirmation of this fact was given, Mr. Grimmett also indicating that pensioners who had meticulously kept records in the past would allow their records after a winter's use of smokeless fuel to be available for examination.

Confessing not to be an expert gardener, reference was made to the observations in Dr. Turner's paper with regard to garden bonfires and Mr. Grimmett took issue with the recommendations made of quick firing and volumes of smoke, for he felt that expert gardeners would feel that the right garden bonfire was one which would smoulder for days and not disturb the neighbourhood but yet retain all the nitrogenous and other chemicals within the remaining ash for garden fertilization. Further if such garden was near to a highway there was the question of road safety and infringement of the Road Traffic Act by the generation of such smoke and it seemed an extremely unwise suggestion to be made by the speaker in the implementation of the desire towards clean air.

Referring to references by previous speakers requiring speedier movement in the implementation of the Act and less cumbersome approach in procedure, Mr. Grimmett suggested that it was necessary to keep one's feet upon the ground and in looking at the maps which were on the Ministry of Housing and Local Government's stand in the exhibition it was apparent that there were those authorities who had not yet implemented Bye-law 24a and who had not indeed commenced smoke control area procedure. He felt that there should be some prodding to move the laggards into action that there then could be a more reasonable approach to the picture as a whole. In reference to the cumbersome procedure Mr. Grimmett drew the attention of Conference that county boroughs were the chief complainants in this direction, that the smaller authorities seemed able to cope with the circumstances efficiently and well, and he naughtily suggested that this point should be brought to the notice of the Boundary Commission.

Alderman Mrs. J. H. Engwell, (Barking), referred to the complaint by earlier speakers that preliminary enquiries before the making of a Smoke Control Order occupied far too much time and used considerable inspector hours.

She said that in Barking they must have some bright inspectors because they were able to deal with a total of 5,000 houses in a period of four months. This was their recent experience. She further pressed the Conference to maintain pressure on the Minister to permit the subsidy to be paid to those householders who voluntarily changed over from burning coal. She said that these volunteers were those who should get the benefit of the subsidy and not householders within the area of the Smoke Control Orders who waited until they were conscripted.

Councillor F. Dawson, (Rawmarsh), reminded delegates that Rawmarsh which was in an industrial area, including Rotherham and Sheffield, had steel and chemical works, slag reduction plants and collieries. He stated that owing to the number of residents receiving concessionary coal, the local authority were faced with a serious problem relative to clean air zones, making reference to Dr. W. C. Turner's paper (Table 14—Concessionary Coal).

Councillor Dawson then referred to the dust and grit from the steelworks, and said it was rather difficult to convince residents in the area adjacent to the works that 80 per cent. of smoke pollution, etc., was due to householders burning coal when looking at the dirty filthy condition of the houses due to industry. He felt it was not beyond the ability of manufacturers of dust catchers or arrestors to evolve something that would prevent dust and grit from blast furnaces spreading over the area. In Rawmarsh it was not necessary to have gauges to measure the emission of dust and grit, it was only too obvious; all one needed was a brush and shovel.

Councillor Dawson concluded by thanking the Sheffield and District Clean Air Committee for all they were doing to convince the industry in that area of the need to get clean air.

P. D. Coates, (Ministry of Housing and Local Government) on his Ministry's behalf congratulated the Society on their initiative in issuing the Questionnaire. He had noted with much interest the views expressed during the discussion.

G. E. Curtis, (Kingswood), drew attention to Dr. Turner's comments in regard to byelaws. In the speaker's experience, enforcement of byelaws made under the Clean Air Act was not as clear-cut as might be supposed. There were snags, common to most local authorities, which sooner or later would give rise to administrative difficulties in extending smoke control areas.

The Clean Air Act did not permit grants to be paid for conversions in dwellings built after the Act came into force, but it did give local authorities power to make byelaws to ensure that only approved appliances could be put in newly-erected houses. Clearly, here was a lead to local councils and the building industry on what was expected of them. Councils did not adopt the model byelaw with alacrity and builders in most instances contained to install the old type grate.

Even when the byelaw was made, it did not apply to dwellings commenced before it came into force; nor was it applicable to a dwelling built *after* the byelaw became operative, if plans were deposited with the council *before* the operative date. Where the byelaw had not been adopted, councils still had no control over the use of ordinary grates.

The significance of all this was that although the Act came into force nearly four years ago, thousands of dwellings built since then had not been fitted with approved appliances, and in areas where the byelaw had not been invoked, this would go on indefinitely.

The speaker had already encountered difficulties. Although the byelaw had been enforceable in his distinct since December 1958, there were houses built under the " non-applicable " rule where the builders put in the old grates. In cases where the byelaw applied, builders put in approved appliances.

To say the least, it was confusing to people without knowledge of the circumstances to be confronted with different standards of enforcement. It did not need much imagination to realize what was likely to happen when the dwellings were included in smoke control areas, and owner-occupiers had to pay the whole cost of conversions. They would not be impressed by legal quibbles and would be only too ready to offer criticism of the local council whether it was justified or not.

Mr. Curtis said that as a result of what had happened in his district, details of which were not germane to the main point of his argument, the council had given directions that a note should be attached to habitation certificates, setting out the position of house purchasers under the Clean Air Act. This at least would make it clear to a purchaser that if he bought a new house in which a stool and fret were fitted he would know the reason for it. The note reads as follows:

KINGSWOOD URBAN DISTRICT COUNCIL

Clean Air Act 1956

Notice to the New Occupier

(1) As you will be occupying the dwelling to which the attached certificate of habitation relates, the Council wish to draw your attention to the provisions of the Clean Air Act 1956 and Byelaws made thereunder.

(2) The Act was passed to implement government policy to rid the country of smoke pollution and ensure a cleaner atmosphere. The operation of the Act will become progressively wider as the years go on.

(3) One of the means of ensuring compliance with the Act is the creation of what are called " Smoke Control Areas," *i.e.* areas in which only smokeless fuels can be burnt in domestic or industrial premises. (Two areas have already been declared in this district and others will follow when the Council decides to proceed further.)

(4) Where Smoke Control Areas are created, a grant of 70 per cent. towards cost of converting existing grates is payable to owners of dwellings *erected before the Act came into force.* As your dwelling was built after this date the owner will not be able to claim grant when a Smoke Control Order is made.
(5) To safeguard the interests of purchasers, the Council made a byelaw in December 1958, requiring all new dwellings to be fitted with approved appliances. If the plan of a dwelling was passed before the byelaw came into operation, although actual construction took place afterwards, the byelaw did not apply. This is the reason why some houses built during the past year or so have approved appliances while others have not.
(6) If ordinary grates have been put in your dwelling it is because the Council had no power to insist on the installation of approved appliances. They have asked that this fact be made known, because at some time in the future you may be required to convert your grates and no grant will be payable for reasons set out above.

If you require any further information please write to, or call to see someone in the Chief Public Health Inspector's Office, Council Offices, Kingswood, Bristol.

W. H. Wattleworth, (Liverpool), said that:

(1) The procedure at the present moment was long and tortuous and unless modification was adopted the local authorities would be deterred from implementing the Clean Air Act. Furthermore, there should be some streamlining to shorten the long period from the commencement of the survey to the date of operation.

(2) Shortly after the local authority had detailed consultations with the Fuel Advisory Committee regarding the availability of fuel and it was found that the number of objectors was extremely small, particularly in respect of large areas, it would appear to be an advantage if some form of quick approval could be given to the applications of those people who wished to carry out alterations.

(3) The information required under the survey was delayed as access to all premises was required and therefore placed the men on overtime and caused exasperation and irritation to the householders, which was unnecessary. A percentage figure, *e.g.* 40 per cent. of the houses could provide sufficient estimate for calculating the requirement of fuel and the amount involved in grant aid.

(4) A great deal of information obtained in the survey due to the long procedure ceased to be of any value having regard to the changes in costs and people's requirements.

(5) Although public inquiries were an essential part of this type of procedure it would appear that the enthusiastic desire to further smoke control rendered the traditional public inquiries with the usual procedure a brake on the progress. For example, in the Liverpool Smoke Control Order No. 10, comprising 27,212 dwellings submitted on 22nd July 1960, there had been few objectors, and from the letters received it would appear that the only objections were in respect of the provision of suitable smokeless fuels. Under the new procedure those points would be considered by the local authorities and easily discussed with any objectors. Was it possible to examine the idea of some form of private inquiry perhaps on similar lines to the slum clearance procedure?

Mr. Wattleworth went on to say that resulting from the recent survey there were persistent "no accesses," and therefore it took six months longer to carry out the survey than originally envisaged.

There were many other technical aspects and traditional objections especially in regard to the use of coke, another respectable name for it would probably help. He said the experience that Liverpool will have shortly when the next large area was completed would give guidance as to whether that traditional resistance could be broken down.

In the nine areas already in operation tremendous interest had been shown by the occupiers to other forms of fuels and it was surprising how many people were turning to electricity and gas as a form of heating.

Mr. Wattleworth thought that the continuous public inquiries and objections were convincing the general public, as a result of adverse publicity, that solid smokeless fuel was difficult to obtain and had many disadvantages for use for normal combustion purposes.

Discussion (Friday morning)

Councillor I. Sweet, (Southwick), in opening the discussion said that her Authority, though small, appreciated the curiosity of women spoken of by Mr. Birtwisle earlier and had sent two women delegates—their Medical Officer, Dr. Rosetta Barker, and herself.

She went on to say that she enjoyed the Exhibition and only wished that it could be more widely seen, perhaps taken as a complete section to the Ideal Home Exhibition in London; warmth, cleanliness and health being the fundamentals of making and running a home.

Having had a cosy half hour thinking far more domestically than municipally, she was then brought back to sad reality. At the Central Electricity Generating Board's stand she read, "If all the coal burnt in this country were burnt in power stations, then the air we breathe would be very much purer than it is today." *Burnt* yes, but what about dust and grit from coal coming to the station, standing uncovered waiting to be burnt and what could be done about ash from the chimneys afterwards? At present nothing at all could be done as could be seen in Mr. Birtwisle's paper on p. 12, Table 9.

She also said that Brighton Power Station on the south coast was coal fed and very new. Some would see it next year. As everything to do with electricity was completely magic to her (by that she meant she did not understand the workings of it) she could give no technical facts except that its two chimneys were 350 ft. high from ground level and that approximately 15,000,000 9 in. bricks were used to build it. Those who liked to make little calculations down the sides of their newspapers could possibly work out its size.

Since the station had been working they had formed a joint committee on Atmospheric Pollution for Hove, Portslade and Southwick to investigate complaints brought to them, which fell into several categories.

The worst—coal dust and fly ash—she repeated, they could do nothing about, as they were not yet covered by the Act.

Their six gauges gave proof of considerable deposits over a very wide area—as did their window-sills!

It was, she supposed, inevitable that dust was discharged when coal was lifted in grabs from the holds of 4,500-ton ships which had brought it to the station quays.

It was also difficult to control the storage piles of coal which were open to the prevailing south-west wind and constantly stirred up by levelling bulldozers. The surrounding wall did little to stop the clouds of dust which blew in the direction of Hove, contrary to public belief that they had no problem in the south. Sprinkling, which was said to generate heat within the piles, might be dangerous. If this was so, why was rain not dangerous?

Fly ash from the chimneys was supposed to pass, watersprayed, down belts and through telescopic chutes to lorries which took it away. But as so often, the human element was the weak link in the chain. It was so much easier not to extend the chute and so much quicker not to cover the lorry afterwards. And more could be carried away when it was dry.

Last year when she was Chairman of the Committee they paid a visit to the power station. They were shown round, lulled by comforting scientific facts and shown graphs, chemical apparatus and enlarged photographs of various particles. Even the fly ash on that occasion was good and wet. They also had a very nice tea and she was photographed looking down a microscope.

Since then the Central Electricity Generating Board had walled in one side of the fly-ash loading bay, which helped, but coal dust was still causing a good deal of annoyance if not a danger to health. That must be a big problem everywhere. She said that, as another Chairman, of their Finance Committee, she appreciated that the new power station was their "Great Goose," but she wished that the egg were gold—*not* brass, for labour-saving reasons.

She concluded by thanking the Chairman for letting her speak about what must be another pantomime character, Cinderella, who was left out of the Act!

A. Harrison Slade, (National Coal Board), began by congratulating the Society and Mr. Birtwisle for their initiative in drawing up and presenting a questionnaire on the working of the Clean Air Act to Local Authorities throughout the country and Mr. Birtwisle for his statesmanlike address and very able summary of the answers to the questionnaire.

The N.C.B. echoed Mr. Birtwisle's sentiments when he said that work must go on and coal must be burned albeit correctly so as to comply with the Act without slowing down the wheels of industry.

He went on to say that the N.C.B. was giving tangible expression of its support of the Act by the intensive operation of its technical service, much of which was directed towards securing reasonable compliance.

Some people were or appeared to be, militant towards the Act because they felt that the drive for clean air was a drive against the use of coal instead of against its improper use. Such people needed persuading that their views were wrong.

The summary of reasons given for the various contraventions was gratifying in the fact that unsuitable fuel was cited in only 8½ per cent. of the cases which compared with 17 per cent. in a summary Mr. Graham, Chief Public Health Officer, Manchester Corporation, compiled covering the years 1946 to 1958 for his district. In each summary the most frequent and overwhelming reason for contravention was bad firing, which bore out Mr. Birtwisle's plea for all operators to be properly trained.

It was unfortunate for all parties concerned that the attitude and approach of various authorities to implementation of certain provisions of the Act were poles apart. That clearly pointed to confident knowledge and experience and its application on the one hand and its lack on the other and the need for central guidance from the Ministry, if not direction. Two examples might be quoted to illustrate the point.

Firstly, some towns were allowing the use of mechanical stokers installed before 1st January 1957 on equal terms with those installed on or after that date as covered by the Minister's exemption order for the industrial use of bituminous coal in smoke control areas while others were rigorously refusing permission.

Secondly, with regard to grit and dust, some authorities satisfied as to effectiveness, have allowed the use of simple and relatively cheap settling chambers incorporated in the flues while others had sought, in similar circumstances, the installation of excessively costly mechanical or electrical equipment.

In that connection it was pertinent to point to the survey that National Coal Board had done on a cross-section of its own boiler plants which showed that in every case except with pulverized fuel firing that the grit emission was well below the highest standards in force in U.S.A. namely 0·25 grains per cubic foot at 500 deg. F. and 50 per cent. excess air equivalent approx. to 0·5 grains per cubic foot at 60 deg. F. and 50 per cent. excess air.

The above National Coal Board results were obtained without the use of arrestors but solely by proper plant operation. The Minister had not seen fit to lay down grit standards yet but until those were in force consumers surely should not be advised or persuaded to install unnecessarily expensive plant to avoid grit nuisance, which correct attention at all times to plant operation could achieve without the aid of any grit arrestor. There was an urgent need for a good and harmonious understanding between local authorities and industry in solving grit emission problems.

S. N. Duguid said that as an individual member he would like to congratulate those local authorities who were already spending so much time, thought and money, on the establishment of "Smoke Controlled Areas," with great benefit to the inhabitants at large. He thought that the contributors to the discussion had spoken with greater confidence and fervour than at any previous conference. It was hoped that the local authorities who had not yet seriously applied themselves to this duty, would take heart and at the next conference it would be possible to report a substantial leap forward.

He was particularly pleased with Mr. Birtwisle's reference to the training of boiler operators and he would ask the gathering to remember that our technical schools and colleges were always willing to put on suitable courses when a reasonable number of students could be mustered. Through the good offices of the City and Guilds of London Institute a ladder had been erected by means of which the ambitious boiler operator could gain the qualification of "Combustion Engineer."

E. J. Winfield, (Castleford), said that he would like to support Mr. Birtwisle in his plea for amendments covering the heights of chimneys. It was wrong that local authority had no control over the heights of chimneys in new construction where persons building were not required to submit plans under building byelaws; it was equally wrong that no control existed over existing chimneys into which new plant was being connected. He would suggest that all new chimneys and all alterations to existing chimneys be brought under the same form of control.

Mr. Winfield went on to say that he would also like to support Mr. Birtwisle's call for compulsory installation of instruments. The Ministry had the power to require their installation and the presence of a smoke density meter with its recording chart would, he was sure, do much to eliminate emissions of dark smoke.

He added that much had been said that morning about observations, but the fact remained that whilst inspectors carried out periodic checks there were many hours when the chimneys were free from visual examination. At weekends and during night workings some degree of slackness could and did enter into boiler house practice; with recording meters this would reveal on check and the very presence of a recording meter would keep the boiler house staff virtually on their toes.

Finally he turned to certification of boiler house operatives of which much had been said. He pointed out that to be of value a certificate of competence must carry with it not only acknowledged status but financial benefit. They all appreciated that the day when the essential qualification of a stoker was strong back and arm muscles had gone; the boiler house of the future will demand more and more technical knowledge. It would be folly to expect vast numbers of men to undertake a course of study and sit for an examination if the certificate issued was only of academic value; time was overdue when certification should be recognised and brought with it a plus rate of wages.

K. Higginson, (Area Engineer, The National Industrial Fuel Efficiency Service), spoke on the training of boiler operators. He pointed out that other than technical school courses there was in existence a correspondence course for boiler operators and that the National Industrial Fuel Efficiency Service had already successfully trained 8,000 operatives under this scheme, but during the past year the number of operatives had fallen to 483. The correspondence course gives the successful candidate the City and Guilds Certificate. He went on to point out that the fall-off in enrolment for the course was not necessarily lack of initiative on the part of the operator, but rather lack of incentive on the part of management. The fully trained certificated operator should receive some acknowledgement by the management of his acquired skills.

E. L. Howe, (British Petroleum Co. Ltd.), said that in Part II of the Conference he spoke in the discussion purely on technical aspects of the paper which he had submitted. He wished to make one or two comments of a more general nature arising not from a purely technical viewpoint but from his position as an observer at the Conference.

He went on to say that the question of the need for scientific measurements was referred to several times and it was obvious that there was considerable support for liaison between scientists, technicians, etc., and the public authorities whose job it was to implement the Clean Air Act. However, some delegates' attitude appeared to be to forget the measurements and get on with the job. There was something to be said for this attitude when the degree and type of air pollution was obvious and not in doubt, *e.g.* visible smoke and fall out of grit and dust. It would be very wrong, however, to just take notice of the obvious and forget other less apparent but equally dangerous factors contributing to air pollution. That was apparently the attitude taken by many people. For instance typical examples occurred many times during Part I of the Conference—Air Pollution from Road Vehicles. Many people complained bitterly about dense black diesel smoke showering other road vehicles without giving a thought to the possible effects of less obvious pollutants emitted by the cars in which they themselves were travelling. In fact diesel smoke was almost the only subject discussed in Part I of the Conference and at times he wondered whether the title should have been changed. They hoped that in the not too distant future when the main object of the Clean Air Act had been achieved, that was to eliminate smoke, dirt and grit, the call would come for intensive efforts to eliminate the insidious, invisible pollutants that so little was known about at present. In the meantime scientists and technicians by measurements and research could fill in the gaps in their existing knowledge and so provide a basis for future legislation.

Returning to the immediate aim of the Clean Air Act to eliminate smoke, grit and dust, it appeared to him that there was one failing that had not been mentioned. That was in connection with soot blowing on boiler plant. During soot blowing periods the quantity of solids emitted was many times greater than during normal running. Moreover the particle size of the materials ejected was comparatively large and so caused quick fall-out and annoying local pollution. It seemed to him a serious failure that stack emissions could be controlled to below Ringelmann 2 for most of the time but the good work was spoilt by short bursts of intensive pollution. He admitted that the solution was difficult, operators were faced with soot blowing to maintain plant efficiency. It appeared that all industrial plant must be fitted with arresting equipment maintained to give a high state of efficiency before they could safely say that smoke, grit and dust had been eliminated.

Dr. P. Feltham, (Association of Scientific Workers) said that the training received by scientists made them specially sensitive to the dangers arising from air pollution. The Association of Scientific Workers had campaigned for legislation long before the Clean Air Act became law. Pollution and measures against it were advancing now as the tortoise and Achilles, the tortoise always leading by a margin. Scientists were impatient with this; advance did not have to be so slow.

Some definite barriers existed to the extension of smokeless zones. Pressure had sometimes to be applied, and touchy problems had to be touched to ensure progress. One such barrier, in areas which needed clean air most, was that smokeless fuel was not available to miners and other employees of the National Coal Board in smokeless zones instead of concessionary coal. He urged the Executive of the National Society for Clean Air to press the

National Coal Board to modify its policy in this respect.

G. Nonhebel, (Individual Member), said, in respect of Mr. Duguid's plea for training of boiler and furnace operators, that there were two additional aspects which were at least as important. The first was that the design of a plant must be correct for the fuel that was to be used and the heat output required. No one would think of trying to burn heavy fuel oil in a stove designed to burn paraffin. If a man were given the right plant for the fuel and tools (that is, instruments) to see that it was working properly he would, with simple training, learn to operate the plant smokelessly though additional instruments would be needed to enable him to run the plant at maximum efficiency. Not many will recollect that when Mr. H. A. Humphrey, a consulting engineer, gave a paper to the 1946 Brighton Conference in which it was suggested that smoke meters should be provided and perhaps made compulsory just as speedometers and trafficators were compulsory on motor vehicles, there was much criticism with this proposal at the time by several smoke inspectors.

As regards fuel, it was most important that the N.C.B. should not only advise on suitable fuels for proposed new plants and for existing plants, but that they should see that deliveries of the right fuel are made in practice. A common comment in recent years has been that clean coal has been delivered by road which was so wet that it was running with water; it had been the practice of the collieries to deliver such wet coal by rail and the water drained out during the period of days taken over the journey.

There still remained criticism of the eight-hour period during which observations should be made of smoke under the regulations issued in connection with Section 1 of the Clean Air Act. The eight-hour period was chosen because that is the normal period of a shift and many operations such as soot blowing are carried out on large plants once or twice a shift, but the operation of soot blowing is conducted on some small plants at intervals of days. The regulations had to be framed to cover all sizes of plants and they covered the installation of modern equipment such as soot blowing in small plants.

The Beaver Committee had asked the B.S.I. to make careful measurements of the minimum amount of smoke that was emitted from well-operated coal-burning industrial plants of modern design. B.S.2978, Part 1, 1958—Measurements of Smoke Emission from Industrial Boilers, Part 1—Medium Capacity Coal-fired Water-Tube Boilers with Travelling Grates had already been issued on minimum smoke from water-tube boilers. The Committee had now issued for industrial comment a further report on smoke emission from shell-type boilers and the Conference would be pleased to hear that only 11 mins. of smoke in a week issued from one of the eight plants studied.

Mr. Harrison Slade had over-simplified the dust problem. It was wrong to think of dust matters only in terms of concentration. The weight per hour of dust emitted and its size were most important, since it was the dust which reached the ground that really mattered. There was need for better technical service from the Coal Board on the choice of dust arrestors for use with particular equipment and fuel, since it was important from the point of view of national economy that unnecessary expensive equipment was not installed. There needed to be some form of published technical appraisal of equipment on the market because it was well-known to specialists that for the same money good or indifferent equipment was supplied.

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HARROGATE CONFERENCE

5th–7th October, 1960

Members and Delegates Attending and Authorities, etc., Represented

Page

Alphabetical List of Members and Delegates 2

List of Local Authorities Represented and Delegates Appointed 13

List of Associations, Firms, etc., Represented and Delegates Appointed 23

List of Overseas Associations, etc., and Delegates Appointed 27

List corrected to 20th September; for additions and alterations inquire at the Conference Office, Exhibition Hall

National Society for Clean Air

Harrogate Conference, 1960

LIST OF MEMBERS AND DELEGATES ATTENDING

A

Adam, W., *Dumbarton*
Adams, G. S., (Area PHI), *Paddington*
Adcock, C. E., (CPHI), *Ilkeston*
Addy, F. B., (CPHI), *Blackburn*
Ainley, A., (Surveyor/SPHI), *Stone*
Ainsworth, G., (CPHI), *Ripley*
Allan, Cllr. Mrs. I. M., *Aberdeen*
Allan, M. B., *National Coal Board*
Allemby, G. H., (PHI), *Dearne*
Allen, G. O., (Dep. CPHI), *Scunthorpe*
Allen, Cllr. W. J., *Skipton*
Ambroso, A., *Marelli Aerotecnica, Italy*
Amende, H. F., *Individual Member*
Anderson, Dr. A., (MOH), *Heston and Isleworth*
Anderson, D., *Boston Marine and General Engineering Co. Ltd.*
Anderson, Sir David, *Individual Member*
Andrew, F. A., (CPHI), *Woolwich*
Andrews, Sir Linton, (*see Conference Handbook*)
Annis, S., *Grahamston Iron Co. Ltd.*
Appleton, Dr. F., (MOH), *Brighouse*
Appleton, W. F., (CPHI), *Portsmouth*
Archer, A. A., (CPHI), *Halesowen*
Ardley, Dr. J., (MOH), *Blackburn*
Arnott, J. F., *Central Electricity Generating Board*
Ashcroft, F. G., *Leamington Spa*
Ashworth, Cllr. Dr. H. K., *St. Marylebone*
Austen, Dr. A. E. W., *C.A.V. Limited*
Austen, T. W., *Woodall-Duckham Construction Co. Ltd.*
Avison, E., (CPHI), *Bedford*
Avy, A. P., *Association pour la Prèvention de la Pollution Atmosphèrique, France*

B

Bale, Cllr. J. N., J.P., *Pontardawe R.D.C.*
Ballard, W. A., *Individual Member*
Barclay, Dr. D., (Dep. MOH), *Aberdeen*
Barkby, J., *National Coal Board*
Barker, Cllr. F., J.P., *Basford R.D.C.*
Barker, Dr. Rosetta C., (MOH), *Southwick*
Barnes, Cllr. H. W., *Blackpool*
Barnett, A. D., *Boston Marine and General Engineering Co. Ltd.*
Barnett, L., *Boston Marine and General Engineering Co. Ltd.*
Barnett, W., *Leslie Hartridge Ltd.*
Barrett, C. F., *Warren Spring Laboratory*
Barstow, Cllr. R., *Audenshaw*
Barton, E. W., (CPHI), *Rochester*
Barty, Cllr. Mrs. A. R., *Beddington and Wallington*
Bastable, N., (CPHI), *Barking*
Batcheldor, S. J., M.B.E., *Leeds Incorporated Chamber of Commerce*
Bate, W., (CPHI), *Cardiff*
Bateman, Cllr. Mrs. M., *Heckmondwike*
Batey, J. W. (Supt. Smoke Insp.), *Sheffield and District Clean Air Committee*
Baxendale, J., *Institution of Gas Engineers* (*see also Conference Handbook*)
Baxter, C., (CPHI), *Todmorden*
Baxter, Cllr. F., *Oldham*
Beardsley, Cllr. W. A., *Southwell R.D.C.*
Beaton, M. M., (SI), *Dumbarton*
Beaumont, S. C., (Chief Smoke Insp.), *Birmingham*
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A1

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NATIONAL SOCIETY FOR CLEAN AIR

HARROGATE CONFERENCE

The Des Voeux Memorial Lecture
to be read at 10.00 a.m.
on Thursday, 6th October 1960

CLEAN AIR, PUBLIC OPINION AND THE PRESS

By

*Sir Linton Andrews, LL.D.**

YOU have paid me the compliment of asking me to deal with a fascinating but difficult subject. The title suggested was " Clean Air, Public Opinion and the Press." Clean air—that's a controversial theme to begin with. In general we all believe in clean air, just as we all believe in lower taxes and lower rates but higher benefits from the State and from local authorities. We can have clean air at a price, but is it a price that many people are willing to pay? The county in which we are met has an old-fashioned maxim of which you will all have heard, " Where there's muck there's money." So the National Society for Clean Air will have to work hard to convert some of our people. It will only succeed if it convinces them that clean air pays.

Public opinion—that, too, is a knotty subject, an extremely interesting one, but not the kind that you can turn up in an encyclopaedia and grasp in a few minutes' careful reading. What makes public opinion? Who make public opinion? How can it be stirred, how guided, how, if necessary, counteracted? How can we make our own private opinions a public force? How can we get the general public on our side in any proposal for reform of which we are sworn defenders, such as the crusade for clean air?

Such questions breed others. Which institution has the most power to influence public opinion—Parliament, the platform, the Press, the pulpit, radio, television, or the ceaseless arguing that goes on in societies, in clubs, in offices, in our homes, about our difficulties, hardships, our pet reforms, our denunciations of wrong, our hopes for a better world here and of a better world hereafter?

One thing is certain amid all this argumentation day after day, that the topics are very largely suggested by the Press. So the Press very properly is the third panel of my triptych subject—triptych, but not, I hope, cryptic. Here I ought perhaps to speak after all my experience of almost sixty years of journalism with more confidence than on other topics, but I am bound to admit that again and again, trying to solve journalistic problems, I have thought of Anatole France's conclusion, " Upon reflection everything becomes difficult."

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* Editor of *The Yorkshire Post*

The Press is very ready to guide but it is extremely difficult to guide the Press. But I shall do what I can to explain its relation to great causes of reform. That, I am sure, is what you have in mind. The thread of continuity in our title leads us straight from the desirability of clean air to the importance of gaining the support of public opinion if our reform is to take effect; we cannot hope for such an outcome of our efforts until we understand the workings of the Press and make the best use of it we can. Such is the logic of our theme.

To begin with clean air: I take it you are all enthusiasts for this boon and I share your zeal for it. Being a journalist I have had to do most of my work in large cities, mainly London, Paris, Sheffield, Leeds and Dundee, from every one of which, no matter what its attractions, it is a joyous relief to escape to the countryside or a sea cruise.

You have taken in hand a sorely-needed crusade to protect us against the smoke, the dirt, the chemicals, the petrol fumes that beset us in our towns, especially the large industrial ones. Every time I go to London the City and West End streets seem to be almost poisonous with the fumes of the traffic. In my boyhood they smelt like a stable. Now they smell like a garage. I much prefer a horsey smell to a horse-power smell.

You have put forward on many occasions a powerful case for remedial and protective measures against these ills. How are you to get your ideas accepted by a powerful majority of citizens? Why is a crusade, which implies hostile opposition, necessary? If people are so fond of clean air, as everyone on holiday is, why the opposition? Is it a general inability to appreciate what science can do for us? Do we need merely a wider spread of information to ensure enlightenment?

The answers to these questions are to be found in human nature. Most of us are public-spirited to the point of applauding the abolition of smoke or the systematic removal of dirt so long as it will not cause us any expense or inconvenience. We welcome the declaration of a smokeless zone unless we find it means we shall have to spend more on our fuel and our fuel appliances. We hear with interest and approval that corporations are building many flats that are electrically heated, but it would be quite a different matter if we found the Corporation was compelling us to transform our own cheerful firesides, where the coal burns so brightly, into a less picturesque if quite clean and efficient form of heating. We welcome the revolution started by the development of diesel trains, but we raise our eyebrows, and perhaps our voices, at the enormous cost of the British Railways modernization scheme —say £1,660,000,000, money to be spent to make money.

The question becomes much more than the simple one, " Do we want clean air or are we content with grimy and fume-laden towns as they are?" We have to settle problems which are both scientific and economic. The manufacturer and the householder will want to know how we propose to reduce the contamination of the air and above all what it will cost them. You may be sure that compulsory fresh outlays of money will impress them more forcibly than conjectural economies. Hence the need to be as accurate and specific as possible when we are arguing that clean air would bring about great economies. There would be less need for the vast sums that the town populations in particular spend on cleaning materials and the replenishment of soiled curtains, bed covers and all the other soft furnishings. Every housewife knows of those sad and annoying occasions when the chimney has begun to smoke and the smoke brings down soot that settles all over a room.

This Society has been working away at this subject for more than sixty years. It has produced excellent reports, excellent schemes. It has done its utmost to ensure that the private opinion of reformers shall become public opinion. Just how can we carry on this process, how speed it up?

In addressing ourselves to public opinion we must be prepared for its rebuffs. Do not believe it to be something invariably intelligent, highly coherent and compact, quickly responsive to sound argument. Many misconceptions prevail about it and in it.

There is the popular doctrine among many people complaining of their lot that *They* do this and *They* prevent that and *They* impose needless hardships. But who are *They?* Some mysterious governing gang who are supposed to enjoy most of the power in this country and who are all united in the desire to exploit the mass of the people. Some people imagine that this mysterious power is exercised by the politicians. If you say, " But surely you don't think the politicians are all of the same mind," the reply is, " Ah, but this is really a sham fight. They may seem hostile on the platform, but in the tea-rooms and corridors of the House of Commons you find them hob and nob together."

Then again some people think the true governing power over the minds of the country is exercised by the Press and in particular by a few Press lords who are supposed to be able to impose their own ideas on everyone. This, too, is obvious delusion. My old chief, Lord Northcliffe, could not make us all eat standard bread and wear *Daily Mail* hats. The redoubtable Lord Beaverbrook confesses that his Empire Free Trade campaign has failed and is very sad about it. What the public shall think is not within the powers of a few people to determine.

So the first point to realize about public opinion is that it derives from all kinds of tributary sources. We must not suppose it is created only by Government experts, editorial writers, the spokesmen of the professions. Political leaders and editorial writers do not always lead and create public thought. They sometimes march with it, sometimes behind it and sometimes against it. Political leaders are often but voices for those who brief them. Government experts propose remedies for ills that business men or humbler citizens have bemoaned repeatedly till something must be done if only to win votes.

Repeatedly is I think the key word here, or, as Mark Twain would have put it, the boss word. Repetition is the soul of journalism: it is also a motive-power of the democratic process. Think of all the discussions over the garden wall, over pots of tea, over pints of beer, over glasses of port. We can imagine how often housewifes in smoky areas complain of smuts on their sheets, blankets and clothes hanging out on wash day. They are not likely to accept these trials with silent stoicism. Sooner or later their experiences will reach the ears of would-be reformers and make an impression.

We have, indeed, a wonderful network of co-operation by which all kinds of plain folk can tell their troubles to men and women with some influence, such as city councillors, trade union officials, voluntary workers for S.S.A.F.A. and the British Legion. These sympathizers—I hope they are always sympathizers with real hardship—may set official machinery in motion or they may take their reports to higher authority, perhaps to Members of Parliament or local editors.

I cannot imagine that if an M.P. had the chance to remedy someone's distress or if a local newspaper could agitate public opinion by calling attention to some grievance the opportunity would be missed, partly because the Member of Parliament wants to stand well with his constituents and the editor wants to increase the influence and sales of his paper. But I would not say their motive was one entirely of self-interest. Our helpfulness to each other in matters of social reform springs largely from our emotion when conscience tells us something is not fair.

It is often, as we know to our cost, a long process before some grievances reach the stage where authority can give a verdict and decide on reform. What to some people may appear a most desirable improvement may seem to others, especially if their pockets are touched, a faddy nuisance. Some people will complain bitterly of how their domestic peace is disturbed by the shattering din of fly-by-night aeroplanes leaving or arriving at a neighbourng airport, but we may be sure that what to some people are hideous winged monsters appeal to others as signs of immense progress in transport, speed that is of the utmost value in saving time for travellers, and creations of an industry that needs national support.

So you have activity by Residents' and Ratepayers' Associations, Townswomen's Guilds, the National Council of Women, the Noise Abatement Society, and all kinds of national societies and associations. I have heard of a national magazine entitled "Q.P." (meaning "Quiet Please.") There are many other kinds of propaganda whose messages are constantly flowing on to my desk with almost the persistent continuity of news flashes. One society, not I think of long standing, claims that already a million words have been spoken to audiences and on television by its honorary secretary and other National Council members.

I can quote from much nearer home an example of what continued effort is necessary to get a simple reform. Leeds has in the heart of the city a hospital with a magnificent history. It is a centre of wonderful achievement, a centre of first-rate teaching, but being in the centre of the city, within a stone's throw of the Town Hall and the Civic Hall, it is exposed to a great deal of noise, even at night time, when cars and motor cycles go dashing past. Some patients, myself among them, have been repeatedly awakened with nightmare shock when convalescent after an operation. There are endless complaints. Appeals have been made to the local Press, the police, the City Council, to everybody who might be supposed to have some influence in the matter, but the nuisance continues. A lighted notice was put up at night saying "Hospital: Quiet Please," but the nuisance goes on. The road on which the offenders tear past is the Queen's Highway. We are told that motorists and motor cyclists who want to go that way, even though they would lose only a minute or two by taking another route, must be allowed to pass. One cannot close the highway to people who want to use it.

I believe that some day for the sake of the unhappy patients we shall get a better arrangement, but it calls for an immense amount of agitation and propaganda. My paper has printed letters, speeches and leaders about it, till readers are bored—unless they happen to be or have been patients at the hospital. Perhaps it is a pity that this is not a party question. If it were it could be discussed at municipal election meetings and the City Council might be more active about it than it has been.

Some of our methods of opinion-forming and public appeal are not as effective as they used to be. The platform is one of the victims of radio and television. Not so many citizens go to public meetings as they did in the days of Gladstone and Disraeli, Joseph Chamberlain and Asquith. The Churches influence the faithful but seem to have less influence than when more people went to the services and kept Sunday as a holy day. The theatre has occasionally in our time done great service to the cause of reform. We remember Galsworthy's plays that deepened the public love of justice, and Shaw's plays that stung us into thinking about social evils. I may be wrong, but I doubt whether the angry young dramatists of today are doing much to emotionalize and direct our belief in great causes.

But there are two institutions which excerise at least as much power as ever. One is Parliament. This remains our incomparable forum. As a frequent visitor to Gallery and Lobby in the past fifty years and a faithful reader of Hansard I see no decline in the power of Parliament to keep citizens well informed. It is true that we no longer have those breathlessly exciting gladiatorial encounters of men like Gladstone and Disraeli, but we have had heart-stirring oratory from men like Winston

Churchill and Aneurin Bevan and homelier warriors keen to get at the facts and put them before Parliament and the whole country. It is true that Victor Grayson, an M.P. for the Colne Valley, not far from here, horrified Edwardians by declaring Parliament a rotten show, but we may be confident that the House of Commons will continue its useful if controversial work long after he has been forgotten.

We may at times be inclined to disparage the slowness of Parliament, and many of us regret some features of its mechanical party war, even though we realize how its wordy battles awaken and maintain an interest in politics among many people who would be indifferent to, say, the intricacies of economic argument. But there is much about Parliament that commands respect. I should place high among its merits the value of question time. It is an education in our democratic system to listen while Members, fortified with information from their constituents and others, are calling the attention of Ministers to matters that seem to demand attention. A question in the House is very often a means of getting some absurd action or some injustice corrected. It may be that it costs a good deal of money to have Civil Servants digging up the relevant facts for their Ministers but there is not the slightest doubt that a question in the House is a valuable popular safeguard, a point which I am sure has not escaped the notice of your Society. It is not true that only at election times can the constituents assert themselves. By keeping an active M.P. well informed they can keep the good work of informing public opinion going steadily forward.

You will not be wondering what is the other British institution I have in mind as one swaying the people with as much persuasion and force as ever. I mean, as you will have guessed, the newspapers. Here you may expect me to have a neat package of opinions ready, the result of long experience. But just as a training in the higher mathematics may be a training in indecision, just as the man who has visited Rome for a week may have sharper impressions of the Eternal City than a man who has been working there for ten years, so it is possible for someone to know so much about the Press that he hesitates to summarize it in swift simplifications without qualifying clauses that crowd upon his mind.

For example, I should find it hard to estimate with any precision to what extent the Press influences public opinion by its own individual policies. We must make an immediate distinction between the influence exerted by the choice and presentment of news and the influence exerted by editorial comment. In theory, news and opinions should be kept apart. Certainly the news should be given honestly and factually and with no desire to gloss over awkward truths. I always respect a paper if I see one of its foreign correspondents is taking a certain line in some important message and the editor in a leading article is taking a rather different line. It is quite reasonable and proper that the man on the spot in a foreign country should see a problem in a different light from that of his editor steeped in the doctrines of his own Government's policy.

It used to be said of the morning paper, the *Standard*, in Gladstone's time that it read as if the entire paper had come from one hand and one mind, those of the editor, William Mudford. That was regarded as a merit, but I should have thought it a weakness except possibly (though I doubt even this) from a literary point of view. What is the use of sending correspondents all over the world if they are merely going to echo in their cables and special articles opinions formed in Fleet Street?

Nevertheless there is bound to be what is often condemned as selective reporting. In theory a paper prints the important news, all of it. But in practice no paper in the world, not even the gigantic *New York Times*, can print (as it professes to do) all the news that's fit to print. Speeches must be condensed. News must be sifted.

Sub-editing must be selective. And selection means that individual taste must come into play. A newspaper largely reflects the personality of its editor—not indeed just his own private prejudices and pet interests, but what he thinks, using his own distinctive judgement, will appeal to readers. He cannot see every paragraph going into the paper, but he is continually trying to school his leader-writers, reporters and sub-editors in the general principles of news selection, news presentment and the style of writing, argument and description he believes in.

Lord Northcliffe used to say that one of the great powers of the Press was the power of the suppress. And so indeed it is. But happily there is such intense competition among newspapers that very few people are inclined to use the power of the suppress in an unworthy way. They would indeed be soon found out. One dear old gentleman, a former M.P., used to write to me almost every week pointing out that in reports of political speeches the *Yorkshire Post* had left out points which he had seen in the *Manchester Guardian* versions, and he roundly alleged that some nefarious person on my staff, if not myself, was cutting out points that told heavily against Tory arguments. Ultimately I had to silence him by proving how often we printed in the *Yorkshire Post* items and points omitted by the *Manchester Guardian*. Selection was unquestionably necessary and it would have been a miracle if both papers, exercising sub-editorial judgement, had condensed in precisely the same way the enormous mass of news pouring in.

Some people imagine that their letters to the editor are wrongly suppressed, but as controversy is the breath of life to a newspaper a sensible editor welcomes pungent, well-argued letters in opposition to his own policy. Only a small number of letters to the editor can be published every day. Sometimes when a topic has whipped up public interest I have had as many as 300 letters in a morning. It is obviously impossible to print more than a tiny proportion of these. Some excellent letters may not get into print. But the commonest causes of rejection are the libels and inaccuracies in which some readers indulge and the lack of new points made by others.

Readers' letters can be intensely interesting. They sometimes have an authority, a closeness of knowledge and a force of expression which are not to be found among journalists who are writing, perhaps to satiety, day after day, week after week, month after month, year after year. Cartoons may be effective, but I doubt whether they sway opinion as much as they did in the days of F. Carruthers Gould, of the *Westminster Gazette*, and Sir John Tenniel, of *Punch*. They had more of a rarity value in Victorian days.

News, with its immediate impact, often unites the whole nation in emotion. An impressive example from journalistic history is that of the revelations from the Crimea by the *Times* war correspondent, Sir William Howard Russell, who opened the eyes of all Britons to the ghastly sufferings of our soldiers, and by his vivid disclosures brought about the fall of the Aberdeen Ministry.

Now we come to the leading articles, still in my judgement the soul of a paper. Some people deride editorials. They say, " After all, it's only one man's opinion." Not so. Even if you have a highly individualistic leader writer like J. L. Garvin, who made the *Observer* famous, or J. A. Spender, whose *Westminster Gazette* leaders were read by all serious politicians, they did not write their articles without incessant efforts to get the latest information from statesmen and to exchange opinions with men of first-class ability. They never wrote in the isolation of a political hermit's cell. The inspiration that Garvin drew from Fisher, the First Sea Lord and the man who modernized the British Navy and had it ready for war in 1914, has been made very plain in a recent book, " The Observer and J. L. Garvin (1908-1914) " by Dr. A. L. Gollin (Oxford University Press).

Very often leaders are decided at an editorial conference. The best thinkers on the staff will contribute, the editor will decide the main line, and the actual leader writer will retire to his typewriter with an abundance of notes. The editor will supervise the resulting article and from his private knowledge will strengthen some surmises, correct deductions he knows to be wrong, and perhaps add more detailed demands than the leader writer attempted and a few epigrammatic touches.

The more serious and weighty the paper the more influential its leaders are. I doubt whether the 200 word leader in snippety basic English, the kind you can get into a couple of inches of fairly large type, can have much influence on the public except by reiteration of the same simple themes time after time. Undoubtedly their readers like to see statesmen given black eyes and bloody noses. The sneer seems to please them more than an argument. Like our party system, this method of attack keeps a great mass of people interested in politics.

There is also warm appreciation of what we call the sunshine Press, with the view that there is no need for heavy taxation, that enterprise should be freed as much as possible and then the profits would roll in and everybody would be happy. Being less given to optimism than some of the more popular papers are I often receive this kind of reproach, " *Must* you give us threepenn'orth of misery every morning?"

It is a good thing that we have all kinds of papers. Democracy provides an arena in which different sides fight it out. Let us by all means toss all the arguments we think important into the midst of the contest and may the best ones win. Perhaps they do. The battle is not always won by the big battalions, or by the party that has the great popular circulations on its side. As long as a party gets ideas under discussion in the democratic arena a strong case has an excellent chance of beating a weak case put forward with the help of a much stronger Press. It is no disparagement of newspapers to say this. It is rather a compliment in implying that newspapers print their opponents' case even though they criticize it and the public is given a chance of making up its own mind.

Having looked at some of the main processes for informing and crystallizing public opinion let us see how we can now use them to further the cause of clean air. Your Society publishes excellent papers on the subject. I was much impressed by one written by Dr. Bronowski on the development of new smokeless fuels. His discussion was lucid and important, especially on the question of premium smokeless fuels. Many housewives would have been cheered by his account of the efforts being made to produce smokeless fuel that is easily handled and stored, reduces the number of times a fire has to be refuelled, ignites easily, burns brightly and long, and picks up well whenever the fire is made. That was the kind of exposition which I think deserves a far wider circulation than in your own journal. It has not had, so far as I saw, the prominence it ought to enjoy in a journalism in which it has to compete for public interest with murder mysteries, film star scandals and tragic accidents to sporting celebrities. Dr. Bronowski did not write only as a scientist for scientists. A good deal of the information he gave could have been popularized for the mass of readers. It could have had a marked influence on public opinion. One must not be too scholarly in manner in trying to persuade the British people of the advantages of clean air. By all means let us have, if possible, statistics showing how respiratory diseases could be reduced by smokeless air. It would be a much more emphatic argument if we could tell all the mothers of this country that if air pollution could be abolished their children could be as berry-brown even in our industrial towns as they are at the seaside.

An appeal to the modern sun-tan worship might be a very effective way of furthering the clean air campaign. Already in towns which have smokeless zones people are noticing how much easier it is to get tanned in the open air. Recently a member of my staff came into the evening editorial conference with a tan as rich as that of somebody just back from the Isle of Capri. He had spent three days watching Yorkshire play cricket at Headingley. Now for 37 years I have been seeing each summer the men who have spent a day or two at a Headingley match: but it is only recently, when the smoke pall over Leeds has become lighter because of certain restrictions on smoke, that I have seen such dramatic tanning achieved in a few hours.

So far as factory smoke is concerned your task should not be a difficult one. For many reasons, labour-saving ones among them, there will be fewer and fewer furnaces stoked to supply the heat and power that industries need. The Englishman with his addiction to the open grate is the man who has to be won over. He has to be converted not only to the idea of clean air—which in general terms he is certain to approve of—but also to the need to play his part in it if he insists on an open fire by using smokeless fuel.

Now if you want to sell anything you have first of all to persuade people that they want it, and then you have to assure them that the price they will have to pay is worth the product they will get. If, as Dr. Bronowski's paper seemed to suggest, they can have a smokeless fuel which has almost all the endearing qualities of coal—easy ignition, bright burning, convenience of storing and handling, reduced problems of ash—it should not be difficult to persuade them that they want it. To offset the disadvantage that they will have to pay more for their glowing smokeless fires than for their blazing, roaring coal fires you will have to hammer home the not so obvious economic gains of smokeless fuel. Extra shillings may have to be spent on smokeless fuel. Very well; show how these can be saved in almost every household by the expenditure saved on the remedies for all the effects of smoke, soot and tarry deposits—the cleaning costs, the repainting costs, the renewal of too-often washed fabrics, the chemists' bills that run up when people are coughing and off their work with smog conditions.

I should like to see incessant emphasis on the value of pure air, emphasis in a form that can be appreciated by all kinds of people, so that the reforms we have in mind become part of the popular thinking. Make the Clean Air Act known to all. Let us enlist the help of M.P.s, of editors of newspapers and magazines, of members of local authorities, of the medical profession, and of scientists generally. You have done extremely good work so far, but we still have to get rid, by every possible means, of the idea that widespread dirt and pollution are an inevitable part of our daily life.

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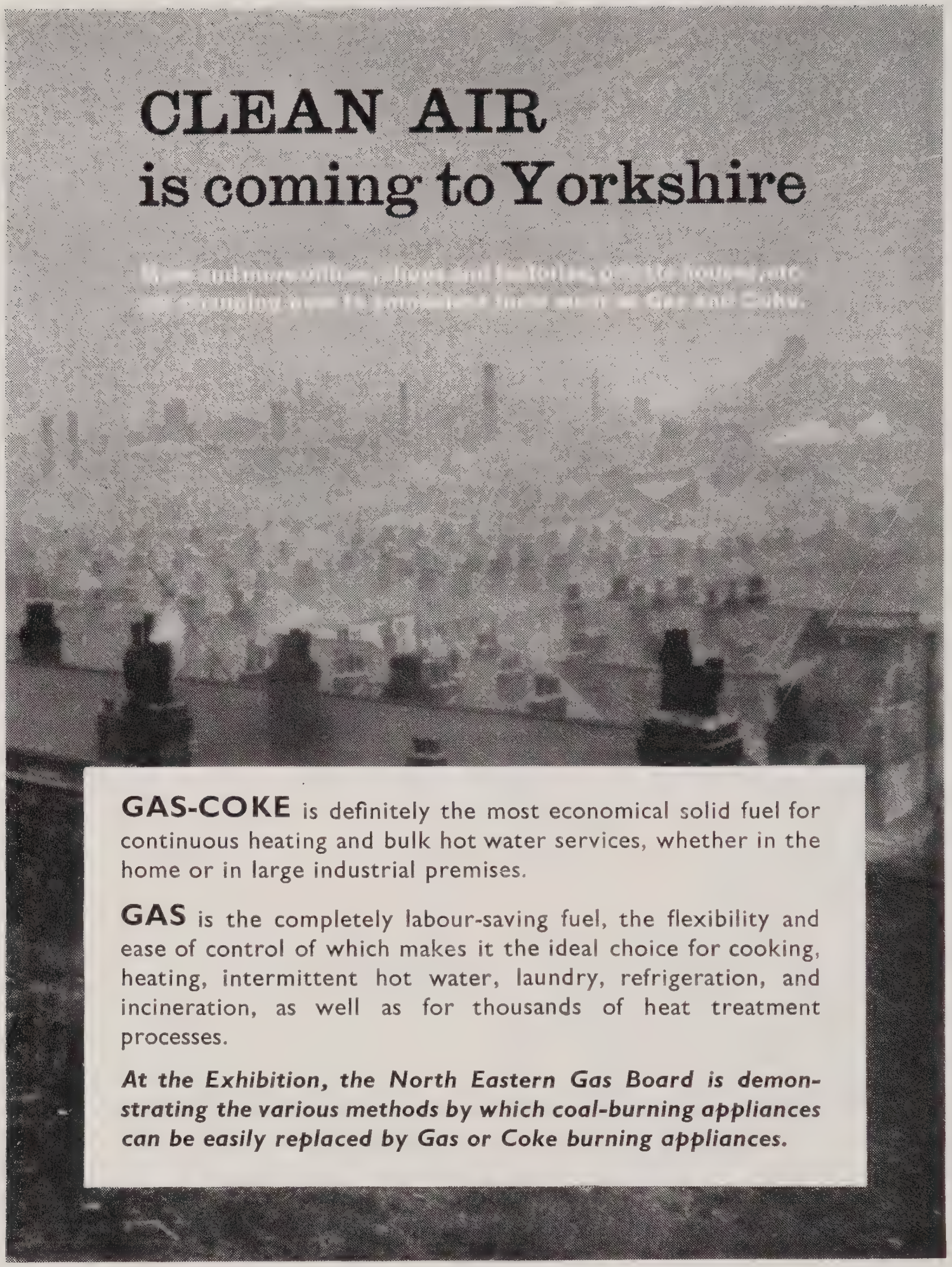

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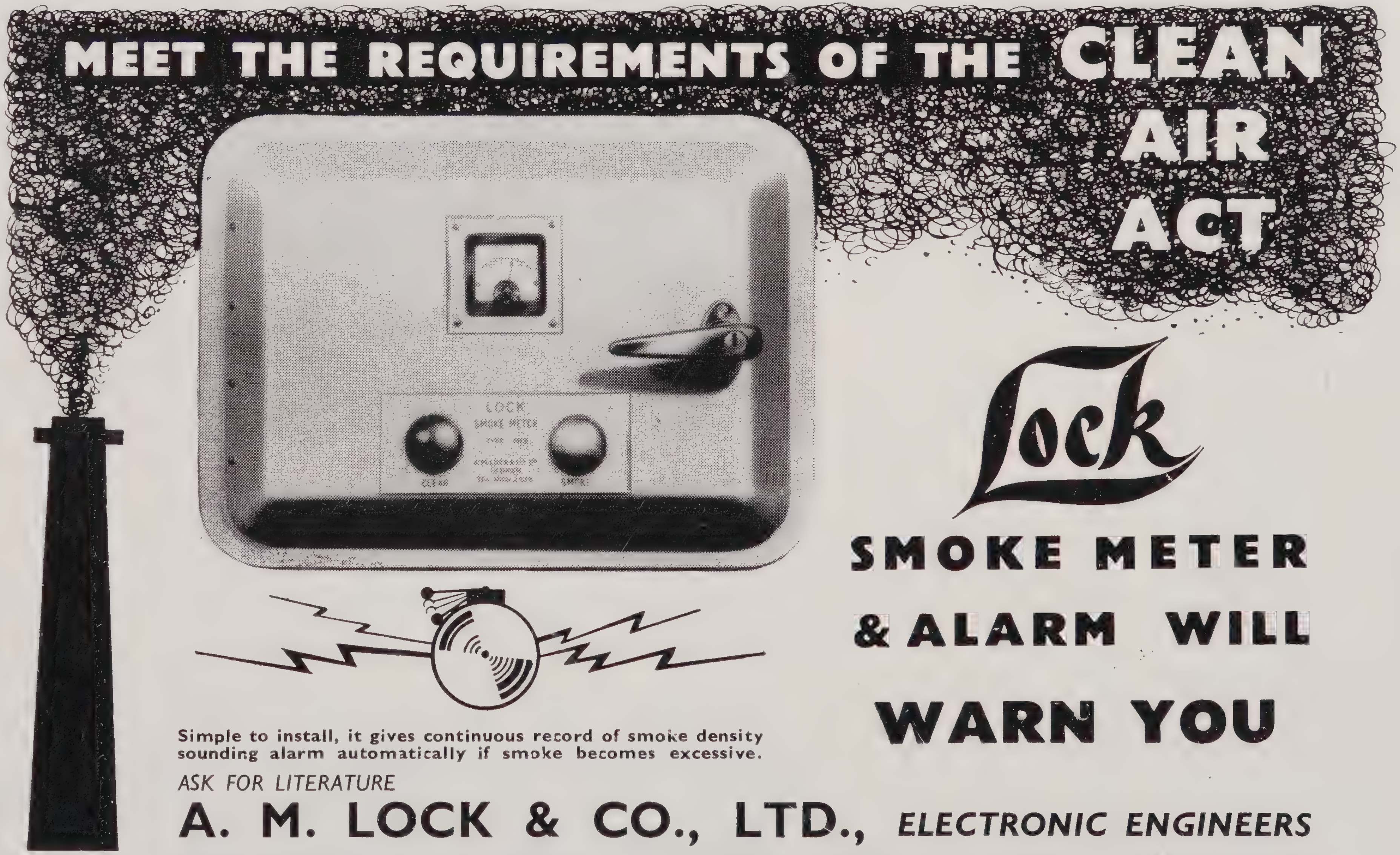

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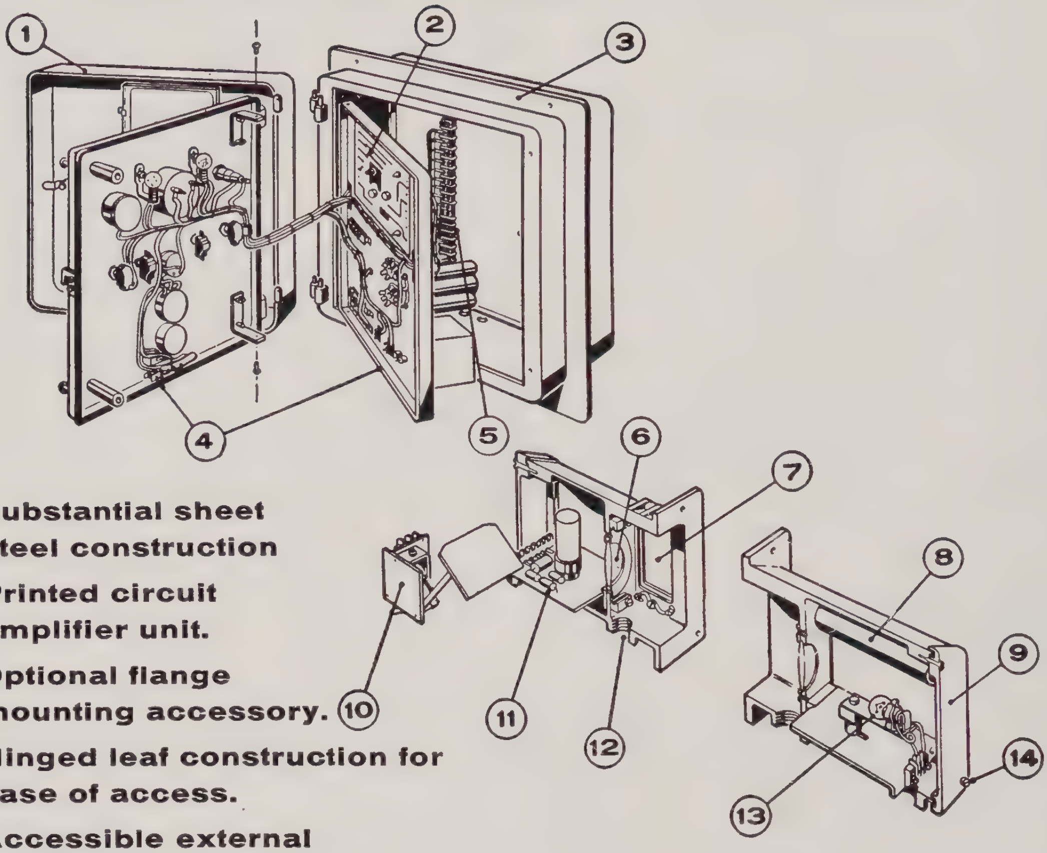

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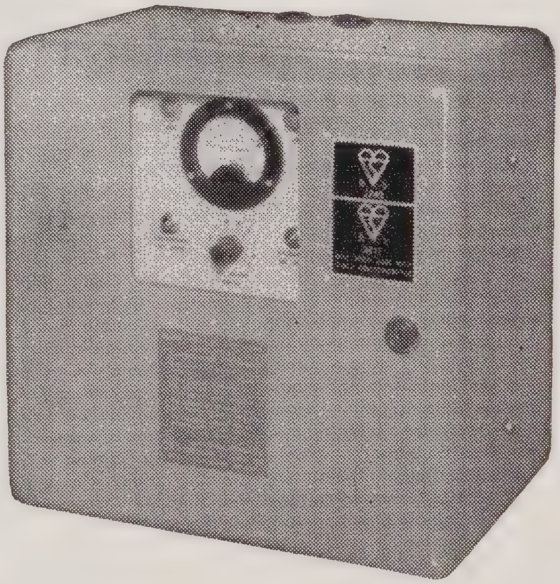

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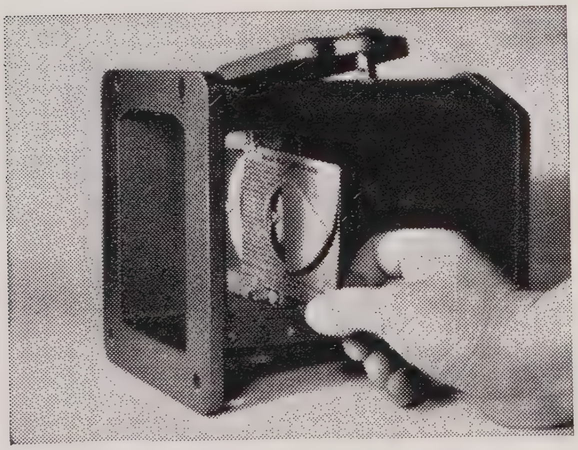

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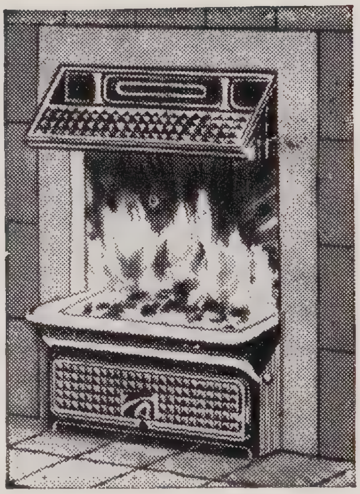

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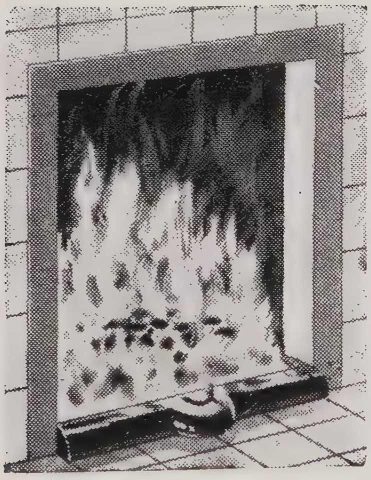

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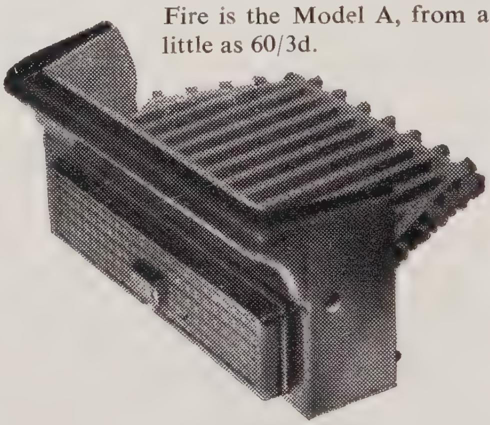

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National Society for Clean Air

27th Annual Conference and Exhibition

Harrogate, 1960

CONTENTS

	Page
Notes on the Conference	17
The 1949 Harrogate Conference	20
About the Society	22
Past and Present Officers, etc.	23
Conference Information	25
Platform Who's Who	26
PROGRAMME	28
Plan of the Exhibition	33
CATALOGUE OF EXHIBITORS AND EXHIBITS	35

INDEX TO EXHIBITORS AND ADVERTISERS

	Stand Description	*Advertisement*
Allied Ironfounders Ltd.	35	34
Associated Electrical Industries Ltd.	36	67
Berry's Electric Ltd.	36	—
Bolton's Superheater and Pipe Works Ltd.	37	64
Boston Marine and General Engineering Co. Ltd.	37	39
British Coking Industry Association	—	cover iii
Calor Gas (Distributing) Co. Ltd.	—	65
Cannon (GA) Ltd.	37	—
Central Electricity Generating Board	38	9
Charrington, Gardner, Locket (London) Ltd.	—	10
Chemical Construction Co. (G.B.) Ltd.	38	12
Coalite and Chemical Products Ltd.	41	40
Coal Utilisation Council	41	—
Combustion Chemicals Ltd.	—	71

continued on page 15

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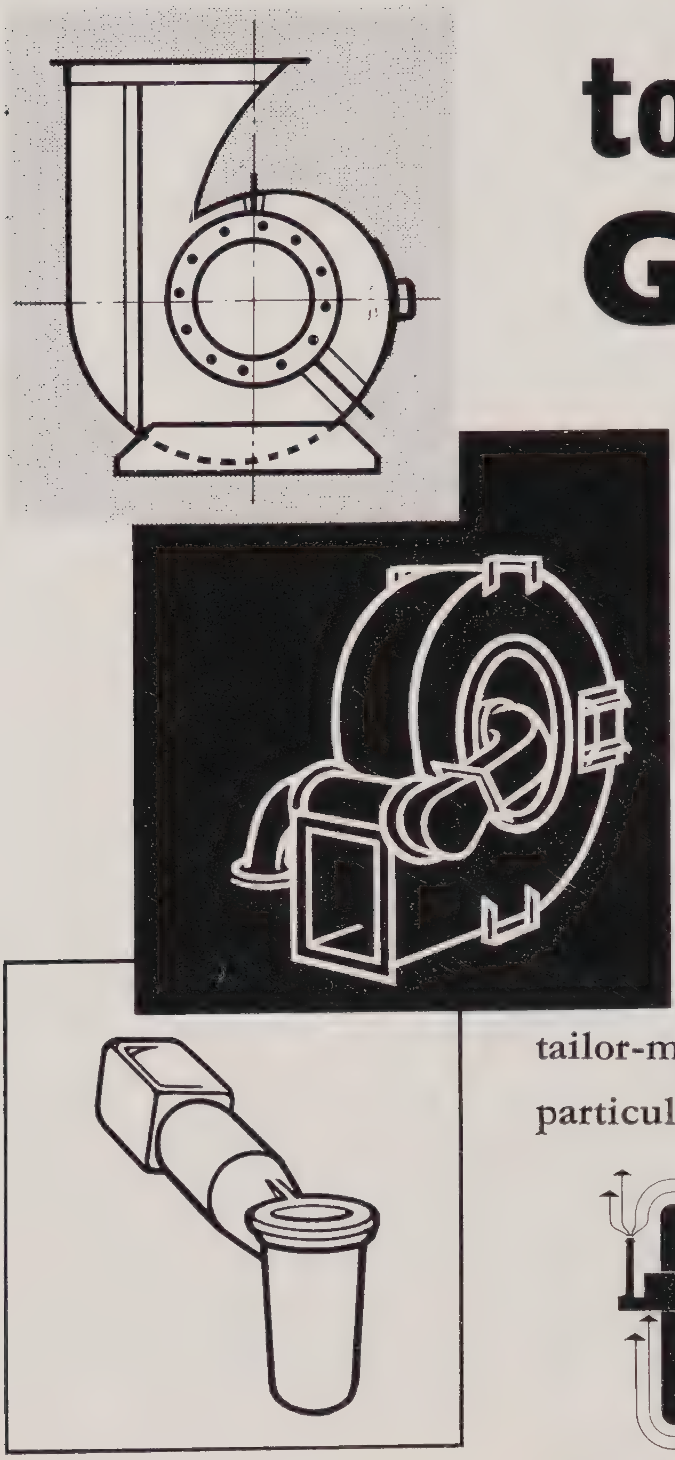

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INDEX TO EXHIBITORS AND ADVERTISERS—*continued*

	Stand Description	*Advertisement*
Combustion Equipment Ltd.	42	—
Crosthwaite Furnaces and Scriven Machine Tools Ltd.	43	—
Davidson & Co. Ltd.	43	—
Department of Scientific and Industrial Research ..	43	—
District Bank Ltd.	45	2
Dunedin Engineering Co. Ltd.	45	—
Electrical Development Association	45	44
Filter-Heat Ltd.	46	—
" Fuel Efficiency "	46	—
General Electric Co. Ltd.	46	—
Grahamston Iron Co. Ltd.	47	66
E. Green & Son Ltd.	48	14
Hargreaves (West Riding) Ltd.	49	—
Richard Haighton Ltd.	—	11
Harris Engineering Co. Ltd.	49	—
Leslie Hartridge Ltd.	50	—
L. G. Hawkins & Co. Ltd.	50	—
W. C. Holmes & Co. Ltd.	51	5
Archibald Johnstone (Engineers) Ltd.	52	—
Charles Knight & Co. Ltd.	52	—
Lancashire Dynamo Electronic Products	—	6 & 7
A. M. Lock & Co. Ltd.	—	4
Lodge-Cottrell Ltd.	52	70
Ministry of Housing and Local Government ..	52	—
" Municipal Engineering "	53	—
National Carbonising Co. Ltd.	53	68
National Coal Board	55	54
National Industrial Fuel Efficiency Service	55	16
National Society for Clean Air	56	66
North Eastern Gas Board	56	cover ii
W. Ottway & Co. Ltd.	56	—
Thomas Potterton Ltd.	57	8
Prat Daniels (Stroud) Ltd.	—	cover iv
Pyramid Press Ltd.	57	—
Radiation Group Sales Ltd.	58	—
Sanigard Appliances Ltd.	58	—
Shell-Mex & B.P. Ltd.	59	3
Simon-Carves Ltd.	59	1
Solid Smokeless Fuels Federation	61	69
Sturtevant Engineering Co. Ltd.	61	60
Thermoduct Ltd.	62	—
Tilghman's Ltd.	63	72
The Women's Advisory Council on Solid Fuel ..	63	—

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Notes on the Conference

THE publication of the conference programme and details of the exhibition in handbook form, inaugurated last year for the International Conference, makes possible the inclusion of a few pages of introductory material. This is the 27th annual conference of the Society, starting with that held in Buxton in 1929, when the National Smoke Abatement Society was formed by the fusion of its parent bodies. The year before that, however, one of these bodies, the Smoke Abatement League of Great Britain, met in Harrogate for what was to be its final gathering. The attendance was about forty, and the meetings took place in a small room in one of the hotels.

The Society met again in Harrogate in 1949, by which time the attendance had grown over tenfold, reaching nearly 450. On another page a brief account of this conference is given, which may indicate the distance travelled during the past eleven years.

After the great success of the Diamond Jubilee International Conference last year there seemed to be a danger that this year's more conventional conference might prove to be something of an anti-climax. But we are confident now that this will not be the case, and it will at once be seen that a programme of exceptional importance and interest has been arranged.

The International Conference in a sense drew our attention from the Clean Air Act and the many problems on our own doorstep to the wider field of air pollution as a world-wide problem and there is no doubt that the exercise was valuable to us in this country as well as to our many friends overseas. This year, however, we come back to our own legislation in full measure. Two of the five sessions are to be devoted to reports and

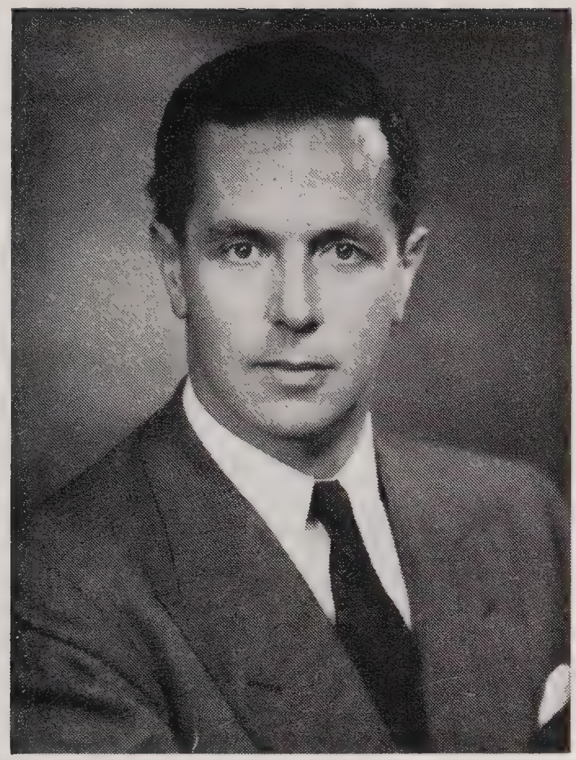
Councillor Leonard Roberts, J.P., Mayor of Harrogate

discussions on the inquiry that the Society has carried out on the working of the Clean Air Act in practice. Over 1,000 local authorities were interested enough to complete and return the detailed Questionnaire submitted to them, and the reports that are to be presented are likely to provide material for comment and question that will easily take up the allotted time.

Three individual addresses of importance will be the Presidential Address by Sir Hugh Beaver, the address to open the conference and exhibition by Sir Keith Joseph, M.P., Parliamentary Secretary to the Ministry of Housing and Local Government, and the Des Voeux Memorial Lecture by Sir Linton Andrews, the distinguished Editor-in-Chief of the *Yorkshire Post*. His subject, " Clean Air, Public Opinion and the Press " is one that everyone who is concerned with clean air should appreciate.

It may not be altogether accurate to say that the nuisance value and danger of pollution is inversely proportional to the height above ground level at which it is emitted, but that there is some law of this kind is suggested by the strong feelings that are aroused among the public by fumes and smoke from diesel vehicles. It is a serious problem, and one that might well grow, even though it can be prevented, as will be shown in the papers that will open the session on the Wednesday afternoon that is to be devoted to the subject.

The remaining conference session is one that, if successful, may give the Society's conference a permanent new feature that could enhance the excellent standing it has already achieved. This is the session for " open



Sir Keith Joseph, M.P.

Sir Linton Andrews

invitation " contributions—short papers and reports on progress, developments and research on all aspects of air pollution and its prevention. The open invitation has resulted in a gratifying—but not embarrassing—response, and delegates will find plenty of material of first-class interest and value. Some of it will be found to bear on the implementation of the Clean Air Act, some on technical aspects, and some on our understanding of the nature and extent of the problem. Time will not permit the reading of these contributions, and we hope that there will be enough time for the discussions that are probable. This session is, frankly, experimental, but if it meets with approval we can hope it will lead to the Society's conference becoming a—if not *the*—recognized platform for the most important reports and announcements of the year.

The sessional chairmen, in addition to the President at the opening meeting, will be the Chairman and two Deputy Chairmen of the Executive Council, Mr. John Innes of Paisley, Dr. J. L. Burn of Salford, and Mr. James Goodfellow of Leeds.

It need hardly be added that Harrogate—conference town that is second to none—will extend its traditional and very friendly hospitality. The Worshipful the Mayor of Harrogate, Councillor Leonard Roberts, J.P., will honour us with a Civic welcome at the opening session, and a Reception on the Thursday evening will be something to be looked forward to.

The Exhibition

This handbook gives you all the essential information about both the conference at the Clean Air Exhibition to be held in the new hall adjoining the Royal Hall. Organized entirely by the Society itself, the exhibition will be the biggest and most comprehensive so far held for the promotion of clean air. There will be—as the lists and descriptions of stands on later pages will show—about fifty exhibitors, who between them pretty well cover the whole of the air pollution control field. We do advise all members and delegates to make an early tour of the exhibition because only then will it be seen that further visits will be needed. The Society's main information and inquiry office will be in the Exhibition hall, not far, it may be added, from the refreshment lounge and bar.

The 1949 Harrogate Conference

This conference came midway between the beginning of the Society's post-war campaign and the London smog of 1952 which so dramatically changed the situation. The programme makes an interesting comparison with that for this present year. In 1949 some of the policies advocated and promoted by the Society were finding acceptance and were being proved useful—the first smokeless zones were coming into being, as were the first local Acts with powers for the prior approval of new industrial fuel-burning installations.

There was a feeling that progress was being made, as indeed it was, and this was evident to the retiring President, Lord Simon of Wythenshawe, who in his Address referred to the Government Committee on air pollution of which he had been a member—the Newton Committee of 1920. He deplored the almost total failure of the Government of the day—and especially the department most concerned, the Ministry of Health—to act on the Committee's recommendations, especially in the field of domestic smoke, which Lord Newton and his colleagues recognized as being at least as serious as industrial pollution. Among other measures they had urged that no housing scheme should be sanctioned unless specific provision was made in the plans for the adoption of smokeless methods, and that the Government should encourage the co-ordination and extension of research into smokeless heating methods. " The Newton report was an admirable document," said Lord Simon. " It is a lamentable fact that so far as action by the Government was concerned it might just as well never have been written."

Lord Simon then reminded the conference of the Committee on domestic fuel policy set up in 1942 by the Minister of Fuel and Power, with himself as Chairman. The report, published in 1946, fully recognized the seriousness of domestic smoke and its recommendations—again not taken up—were very similar to those that were to be made, eight years later, by the Beaver Committee. They included proposals for the gradual replacement, through smokeless zones, of bituminous coal by smokeless fuel, gas and electricity in the home. The Simon Committee thought it could be done in 20 years; the Beaver Committee in 10 to 15 years.

Another address of note was by the Parliamentary Secretary to the Ministry of Health, Mr. Arthur Blenkinsop, M.P., who naturally referred to the recent action of his Ministry to implement, in part, one of the steps forward for which the Society had been pressing—requiring the installation in new local authority houses of appliances suitable for solid smokeless fuels. One of the two resolutions passed by the conference was in fact to welcome this—and to hope that it would be extended to cover privately built houses. The other resolution deplored the use in local authority houses that were equipped with smokeless fuel appliances, of bituminous coal, the smoke from which was " in some cases exceptionally offensive from its being emitted at a low level from prefabricated bungalows."

Among the papers presented and discussed were a number of " Progress Reports," including reports on smokeless zones and prior approval in practice (through local Act); a contribution by Dr. Parker (now a member of our Executive Council) on the work of the Fuel Research Station; a paper by Mr. Eric Sinkinson, Lecturer in Fuel Technology, Leeds University with the intriguing title " The Case Against Smoke: An Outside View"; and a paper by J. Carr, an N.C.B. scientist, on the problem of smoke and fumes from burning colliery spoilbanks. (The great improvement in this problem since then is shown by the complete absence of any demand that we should again discuss it.)

Another report was on District Heating, which in the early post-war years was regarded by many as the coming system for better and smokeless domestic heating, but which has—perhaps unfortunately, because it has many merits—not fulfilled hopes.

The conference was the first to be attended by the new President, Dame Vera Laughton Mathews, whose death last year was a great loss to the Society and to its meetings.

In retrospect, Harrogate 1949 can be seen to have been a good, practical and useful conference, typical of the steady but slow progress being achieved before the deluge—the deluge being of course the 1952 smog and its sequels, the Beaver Report and the Clean Air Act. The difference between the programmes for 1949 and 1960, especially in the emphasis and attitudes they reveal, show very clearly indeed the remarkable progress that has been achieved during the eleven years.

For New Delegates

ABOUT THE SOCIETY

Those who are attending the Conference for the first time may wish to know more about the National Society for Clean Air. As we celebrated our Diamond Jubilee last year with a special International Conference it will be seen that the Society has quite a long history. Starting in a very small way with but a handful of private individuals, the Coal Smoke Abatement Society was formed in 1899. It did valuable pioneering work and accomplished the first necessary stage of making it understood that clean air was not the impractical fad of a few cranks. It did much behind the scenes when the Newton Committee (mentioned on another page) was set up, and co-operated with a provincial association that had been formed in 1909, the Smoke Abatement League of Great Britain. In 1929 the two bodies joined together to form the National Smoke Abatement Society.

This name was retained until 1958, when it was changed to the present one, and at the same time, to put its membership and finances on a recognized business footing, it became a Company Limited by Guarantee and not having a share capital. It is licensed by the Board of Trade to omit the word " Limited " from its name and for Income Tax purposes it is recognized by the Board of Inland Revenue as a Charity.

The Society is a voluntary organization essentially subsisting on the subscriptions of its members, and it does not receive any official grant or subsidy. Its members include individuals, local authorities and firms, associations and other corporate bodies. Although local authorities—over 500—constitute the largest class of membership the corporate members make the largest class of subscriptions. The Society is governed by an Executive Council consisting partly of elected representatives of members on a divisional basis, and partly of the appointed representatives of national organizations in membership. The Divisions are Scotland, North West, North East, Yorkshire, West Midlands, East Midlands, South East, South Wales and Monmouthshire, South West and Northern Ireland. There are Divisional Councils of members, with their own committees and honorary officers, in each of the Divisions except the last two.

The Society's objects are, in brief, to promote clean air by education, publicity and similar means, to encourage the adoption of means for clean air, and generally to help to create a public opinion in favour of these objects. Its main activities are the publication of a journal, Year Book and other literature, the holding of conferences and meetings, providing educational and publicity material, information and other services, and co-operating with others.

The Society and its parent bodies have many achievements to their credit, from pioneering the training of boilerhouse firemen and the regular measurement of air pollution to the conception and advocacy of smokeless zones and prior approval. The Inquiry into the

Working of the Clean Air Act, which is to be reported and discussed at Harrogate, is an example of the kind of work the Society is well fitted to perform.

Today, with the new Act in force, the opportunities for useful activity by the Society are greater than ever before, and are in fact both needed and demanded more than ever before. But much remains undone because its income is only a tithe of what could be used to advantage. New members, and more new members, are needed—and if you, as a delegate to this conference, can help us to secure them you will be doing a very good turn to the cause of clean air.

National Society for Clean Air

formerly the

National Smoke Abatement Society

Present and Past Officers, etc.

President: Sir Hugh Beaver, K.B.E.

Senior Vice-President: Sir Graham Sutton, C.B.E.

Immediate Past-President: Dr. R. Lessing, C.B.E.

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North East: Alderman B. N. Young, G. W. Tate.

Yorkshire: A. C. Saword, James Goodfellow.

West Midlands: Councillor W. A. N. Jones, W. L. Kay.

East Midlands: G. A. Hiller, A. Wade, M.B.E.

South East: Alderman C. H. Smith, O.B.E., J. J. Matthews.

South Wales and Monmouthshire: Vacant.

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Administrative Secretary: L. Nevard.

Information Officer and Librarian: H. C. F. Kapps.

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Conference Information

Meeting Place

All meetings and social events will be in the Royal Hall.

Registration

A Registration Card will be enclosed with this Handbook, and you are requested to complete this and hand it in at the Society's Information Desk, or to a Steward, at the first session attended.

Discussions

Those wishing to speak in the discussions should complete and hand in a printed Discussion Card which may be obtained from the Society's stand or Steward in the hall. All speakers are requested to: (*a*) condense their remarks as much as possible, and (*b*) confine them to the specific questions raised in the papers being discussed. The time allowed for contributions will normally be limited to three minutes. Those who take part in the discussions and wish to have their remarks recorded are asked to send a condensed copy of their remarks, in reported speech, to the Director not later than October 17th.

Resolutions

The following conditions for the submission of resolution are stipulated by the Executive Council:

(*a*) Any resolution it is desired to submit must be relevant to matters under discussion at the conference.

(*b*) No resolution may be moved except by prior approval of the Resolutions Committee.

(*c*) A copy of the proposed resolution must be received by the Director not later than 10.30 a.m. on Wednesday, October 5th, or preferably by post (at the Society's offices) on or before September 30th.

(*d*) Resolutions will be moved at the end of the Friday morning session only.

List of Delegates

A printed list of delegates will be available at the Society's stand in the Exhibition.

Proceedings

All the Papers, Addresses, discussions and any resolutions adopted will be published in volume form as the *Proceedings* of the Conference. A copy will be forwarded free of charge to all registered delegates and extra copies will be available at about 25s. each.

The Exhibition

The Clean Air Exhibition, organized by the Society in conjunction with the Conference, will be held in the Exhibition Hall adjoining the Royal Hall. Open from 9.30 a.m. to 5.30 p.m. on the Wednesday and Thursday; to 12.30 p.m. on Friday. Admission will be free to all delegates, and to non-delegates on presentation of an invitation card.

Bookstall

There will be a bookstall of the Society's, H.M. Stationery Office and other publications as a part of the Society's Stand in the Exhibition.

Bank Facilities

Full banking facilities will be available to all attending the Conference or Exhibition, from the District Bank, Ltd., at Stand F.1 in the Exhibition.

General Inquiries

The Society's staff at the Conference Office (see Exhibition plan) will be pleased to assist with any inquiries on matters not mentioned above.

Platform Who's Who

Andrews, Sir Linton, LL.D. Editor of the *Yorkshire Post;* foundation member and former Chairman of the Press Council; former President of the Institute of Journalists and of the Guild of British Newspaper Editors.

Baxendale, John, M.Inst.Gas E., A.M.Inst.F., A.R.Ae.S. General Manager, Bradford Group, North Eastern Gas Board.

Beaver, Sir Hugh, K.B.E., LL.D. President, National Society for Clean Air; Chairman of the Government Committee on Air Pollution and member of the Clean Air Council.

Birtwisle, E. M., M.R.S.H., F.A.P.H.I. Chief Public Health Inspector, Horsforth Urban District Council. Member of the Executive Council, National Society for Clean Air.

Burn, J. L., M.D., D.Hy., D.P.H. Medical Officer of Health, City of Salford. Joint Deputy Chairman of the Executive Council, National Society for Clean Air.

Carroll, Miss J. D. Warren Spring Laboratory, D.S.I.R. Engaged on microsurveys of smoke and sulphur dioxide concentrations in the atmosphere.

Christie, D. H., A.F.C.E., Stud.Inst.F. Senior Assistant, Fuel and Furnace Research Section, Research and Development Department, The United Steel Companies Limited.

Cooke, J. O., B.Sc. Coke Manager, The Gas Council. Member of the Executive Council, National Society for Clean Air.

Craxford, S. R., B.A., D.Phil. Head of the Atmospheric Pollution Division, Warren Spring Laboratory, D.S.I.R.

Eaton, F. J., B.Sc., Ph.D., A.R.I.C., M.Inst.Gas.E. Deputy Manager, North Thames Gas Board, Watson House. Member of the Executive Council, National Society for Clean Air.

Fuidge, G. H., B.Sc. Manager, Central Laboratories, South Eastern Gas Board.

Goodfellow, J., F.R.S.H., M.I.P.H.E. Chief Public Health Inspector, City of Leeds. Joint Deputy Chairman of the Executive Council, National Society for Clean Air.

Gray, F. A., F.Inst.F., A.I.M. Fuel Consultant, The United Steel Companies Limited.

Howe, E. L., A.M.I.Mech.E. Engineer, BP Research Centre, British Petroleum Company Limited.

Innes, John. Chief Sanitary Inspector, Paisley Corporation. Chairman of the Executive Council, National Society for Clean Air.

Jarvis, W. D., A.M.Inst.F. Head of the Fuel and Combustion Section, Power Generation Branch, Research and Development Department, Central Electricity Generating Board.

Joseph, Sir Keith, M.P. Parliamentary Secretary, Ministry of Housing and Local Government.

Lees, B., A.R.I.C., M.Inst.F. Industrial Fuel Technologist, formerly with the Central Electricity Generating Board.

Lister, D., F.R.S.H., F.A.P.H.I. County Health Inspector, Northumberland. Winner of the " John S. Owens Prize " of the Royal Society of Health, 1955, with essay " The Problem of Engine Exhaust Fumes from Road Vehicles " and author of " Atmospheric Pollution from Road Vehicles " (Association of Public Health Inspectors Fellowship Thesis, 1957).

Lock, J. K. Engineer, BP Research Centre, British Petroleum Company Limited.

Meade, P. J., O.B.E., B.Sc., A.R.C.S. Assistant Director, Meteorological Office.

Morley, M. C. Group Chemist, London Division, Central Electricity Generating Board.

Newall, H. E., D.Sc., Ph.D., A.R.I.C. Warren Spring Laboratory, D.S.I.R. Concerned with abatement of the pollution of the atmosphere by sulphur dioxide.

Pengelly, A. E., B.Sc., A.Inst.P. Head of Fuel and Furnace Research Section, Research and Development Department, The United Steel Companies Limited.

Reed, L. E., M.Sc.(Eng.), A.M.I.Mech.E. Warren Spring Laboratory, D.S.I.R. Concerned with abatement of pollution of the atmosphere by road vehicles and oil-fired boilers.

Roberts, Councillor Leonard, J.P. Mayor of Harrogate. (See page 18).

Slade, Harrison, B.Sc.Tech., F.Inst.F. Chief Fuel Technologist, Marketing Department, National Coal Board Headquarters.

Slimming, D. W., M.A. Warren Spring Laboratory, D.S.I.R. Engaged on air pollution work at the Thorntonhall (Glasgow) Branch of Warren Spring.

Squirrell, F., M.Inst.F. Chief Engineer, Metropolitan Engineering Co. Ltd.

Turner, W. C., M.D., B.S., M.R.C.S., L.R.C.P., D.P.H., D.I.H. Medical Officer of Health, Metropolitan Borough of Poplar. Member of the Executive Council, National Society for Clean Air.

Wallin, S. C. Warren Spring Laboratory, D.S.I.R. Engaged on investigations of pollution by road vehicles.

Waring, G. J., A.M.I.M.E. Development and Proving Engineer, Leyland Motors Limited.

Weatherley, Mrs. M.-L., P.M., M.A. Warren Spring Laboratory, D.S.I.R. Engaged on the National Survey, microsurveys of smoke concentrations and dispersion of chimney gases.

Wilkins, E. T., Ph.D., M.Sc., M.Inst.F., M.R.S.H. Warren Spring Laboratory, D.S.I.R. Engaged on the chemical nature and reactions of pollutants.

Williams, F. P. Warren Spring Laboratory, D.S.I.R. Concerned with interpretation of the results of the Co-operative Observations.

Wilson, D. G., A.C.I.S., A.C.W.A. Coke Officer, North Eastern Gas Board.

Wilson, D. S., B.Sc. Assistant Scientist, engaged in the study of air pollution around power stations, Fuels and Combustion Section, Power Generation Branch, Research and Development Department, Central Electricity Generating Board.

More Information

Rail Travel

Inquiries about rail travel, seat reservations, etc., may be made at the British Railways Bureau, Stand H.4 in the Exhibition.

Refreshment Facilities

The attention of those attending the Conference or Exhibition is drawn to the Bar and Coffee Lounge, and to the additional Rest Lounge, as shown on the plan of the Exhibition.

Programme

of the

Conference

All meetings in the Royal Hall, Harrogate

Wednesday, 5th October

Morning

9.30 Exhibition open.

10.30 **Opening Session**

Chairman: Sir Hugh Beaver, President.

Welcome by the Worshipful the Mayor of Harrogate, Councillor Leonard Roberts, J.P.

Address and Opening of the Conference and Exhibition by Sir Keith Joseph, M.P., Parliamentary Secretary, Ministry of Housing and Local Government.

Presidential Address by Sir Hugh Beaver.

12.30 approx. Lunch adjournment.

Wednesday, 5th October

Afternoon

2.30 **Session on Air Pollution from Road Vehicles**

Chairman: Dr. J. L. Burn.

Presentation of Papers:

The Administrative Control of Smoke from Road Vehicles, by D. Lister.

Prevention of Air Pollution by Diesel-Engined Road Vehicles, by G. J. Waring.

Methods of Removing Smoke from the Exhausts of Diesel Engines, by L. E. Reed and S. C. Wallin.

Some Factors Concerning Diesel Engine Exhaust Fumes, by J. K. Lock.

Discussion

(The Papers, which will be included in the Pre-Prints, Part I, will be introduced, but not read, by the Authors).

4.30 approx. Close of Session

5.30 Exhibition closes

Thursday, 6th October

Morning

9.30 Exhibition open

10.00 *The Des Voeux Memorial Lecture*
Chairman: John Innes.

" Clean Air, Public Opinion and the Press," by Sir Linton Andrews.

(*The Lecture will be read. Printed copies will be available after the Session from the Society's Information Stand in the Exhibition Hall*).

10.45 **Session of " Open Invitation " Reports and Papers**

Group I—Research and Investigation Reports

The Assessment of Liability to Smog in Terms of Weather, by P. J. Meade.

Current Research Projects on Air Pollution by the Central Electricity Generating Board, by W. D. Jarvis and D. S. Wilson.

Sampling for 3:4 Benzpyrene in Flue Gases from Plant Fired by Petroleum Fuels, by E. L. Howe.

Trends in the Pollution of the Air of Great Britain by Smoke and Sulphur Dioxide, 1952–59, by J. Carroll, S. R. Craxford, H. E. Newall and M.-L. P. M. Weatherley.

Pollution Levels in Cities, by F. P. Williams.

Accuracy and Reliability of Instruments in Common Use for the Measurement of Air Pollution, by S. R. Craxford, E. T. Wilkins and D. W. Slimming.

Group II—Domestic Heating Reports

Report on B.S. Coke, by J. O. Cooke and Dr. F. J. Eaton.

Smoke Control in Action—13 Years Experience at Bradford, by D. G. Wilson.

The Modification of Side Oven Ranges by Means of the " Cokeburn Unit," by J. Baxendale.

Recent Developments in the use of Gas for Domestic Heating, by G. H. Fuidge.

Group III—Industrial Reports

Dust Sampling Provides Air Pollution Control, by B. Lees and M. C. Morley.

The Prevention of Smuts from Oil-Fired Boilers at Low Loads, by F. Squirrell.

The National Coal Board Technical Sales Service and the Clean Air Act, by Harrison Slade.

Measurement of Dust Emission from Steelmaking Furnaces, by D. H. Christie, A. E. Pengelly and F. A. Gray.

(*These Reports will be printed in the Pre-Prints, Part II. They will not be presented verbally but the Authors will answer questions*).

12.45 approx. Lunch adjournment.

Thursday, 6th October

Afternoon

2.30 **First Session on the Inquiry into the Working of the Clean Air Act**

Chairman: James Goodfellow.

Presentation of Report on Smoke Control Areas, etc., by Dr. W. C. Turner.

Discussion

4.30 approx. Close of Session

8.30 **Reception** at the Royal Hall by the Worshipful the Mayor of Harrogate (by invitation).

Friday, 7th October

Morning

9.30 Exhibition open

10.00 **Second Session on the Inquiry into the Working of the Clean Air Act**

Chairman: John Innes.

(1) Presentation of Report on the Industrial Sections, by E. M. Birtwisle.

(2) Discussion on Mr. Birtwisle's Report.

(3) General Discussion on the Inquiry as a whole.

12.00 approx. Any Resolutions (*see under Conference Information*)

Vote of thanks

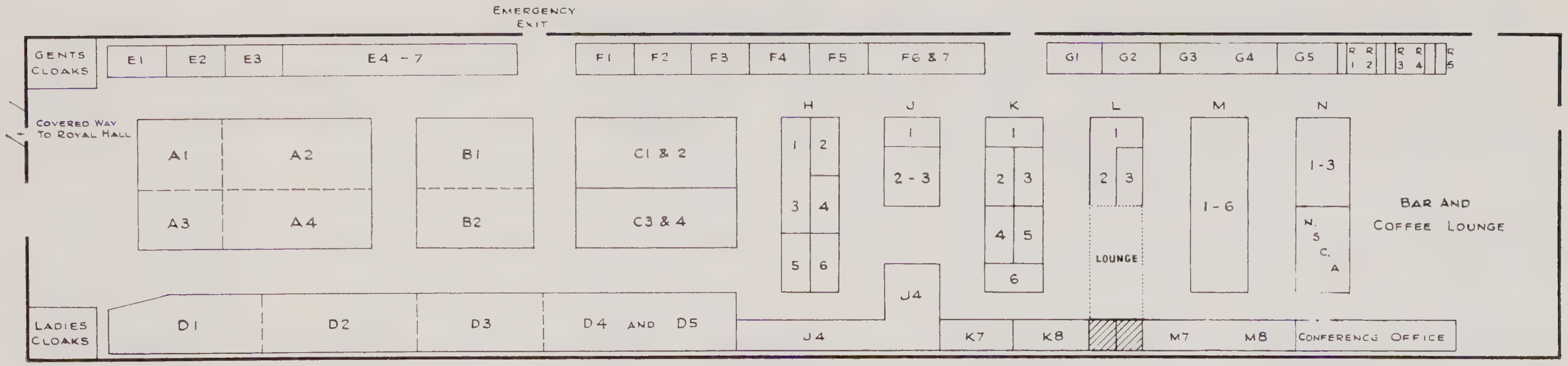
12.30 Close of Session and Conference

Exhibition closes

Previous Conferences of the Society

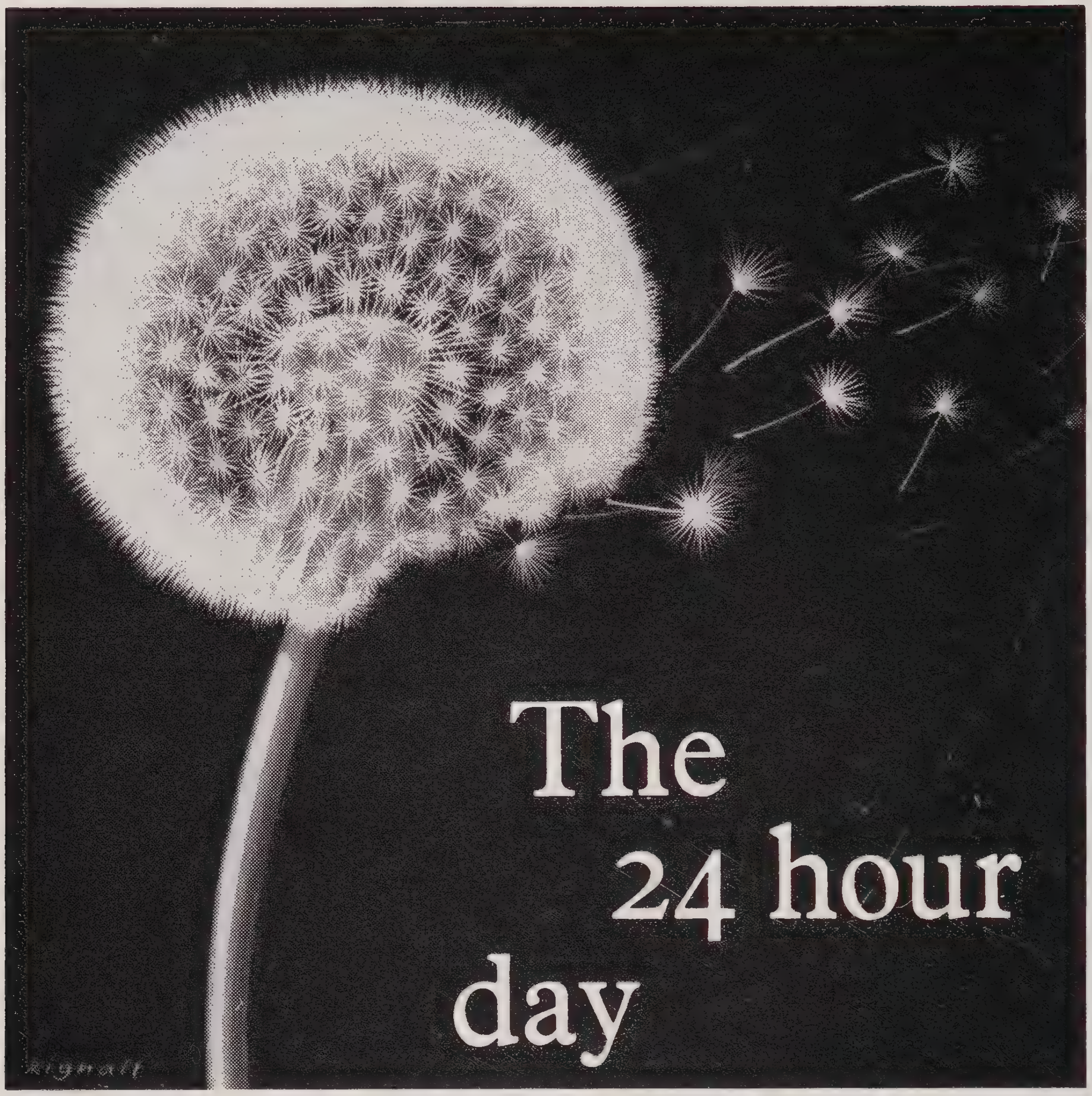
1929	Buxton
1930	Leicester
1931	Liverpool
1932	Newcastle-upon-Tyne
1933	Sheffield
1934	Glasgow
1935	Bristol
1936	London (Science Museum)
1937	Leeds
1938	Cardiff
1943	London*
1945	London*
1946	Brighton*
1947	Edinburgh*
1948	Cheltenham*
1949	Harrogate*
1950	Margate*
1951	Blackpool
1952	Portsmouth*
1953	Glasgow*
1954	Scarborough*
1955	Bournemouth
1956	Southport*
1957	Hastings*
1958	Llandudno*
1959	London (Diamond Jubilee International)*

* *Proceedings still available. For prices and other details see current Clean Air Year Book.*



Plan of the Exhibition Hall

Showing Position and Numbers of Stands



Right around the clock the Allied products are working hard for their living. Cookers cooking splendidly . . . kitchen units storing roomily . . . boilers heating baths soothing . . . fires cheering . . . pipes piping and harvesters gathering. Their names speak for themselves . . . Aga, Rayburn, Leisure. Household names all. Allied Ironfounders are working at home, in industry and down on the farm. All adding to the already remarkable reputation of this vast organisation.

ALLIED IRONFOUNDERS

28 BROOK ST LONDON W1 ENGLAND

Makers of AGA and RAYBURN COOKERS · FIRES and BOILERS · LEISURE KITCHEN UNITS and SINKS
VOGUE and ELYSIAN BATHS · GAS and ELECTRIC COOKERS · CAST IRON PIPES · HEAVY DUTY
COOKERS and CATERING EQUIPMENT · LUNDELL and WREKIN AGRICULTURAL EQUIPMENT

THE EXHIBITION

In the Exhibition Hall adjoining the Royal Hall. Open from 9.30 a.m. to 5.30 p.m. on Wednesday and Thursday, 5th and 6th October, and from 9.30 a.m. to 12.30 p.m. on Friday, 7th October.

LIST AND DESCRIPTION OF EXHIBITS

The information given in this list has been supplied by the Exhibitors and no responsibility for any of the statements or descriptions can be accepted by the National Society for Clean Air.

Stand No.

M1 to 6 **ALLIED IRONFOUNDERS LIMITED, 28 Brook Street, London, W.1.**

Allied Ironfounders Limited, the country's largest producers of cooking, space and water heating appliances, cast iron pipes, baths and kitchen equipment, will display 11 smokeless fuel appliances; a cooker, three types of boilers, five fires, a convector fire, and a room heater.

The *Rayburn Regent Cooker* and water heater burns coke, anthracite or other smokeless fuels.

Boilers on display include the SF20, designed to burn gas coke or other similar smokeless fuels; it has a thermostat to control burning rate. *The Kayenco Boiler* is gas fired and fully automatic. It is approved by all United Kingdom Gas Boards and complies with British Standard specifications. The *Watts Automatic Gravity Feed Boiler* is specially designed to give great heat concentration from a small fire and thus provides maximum heat extraction from the fuel. For space heating and supplying hot water it is exceptionally clean and efficient in use and simple to operate.

Fires on display will be the *Lowburn Drop Front Fire* for high radiant output at low level. The *Lexham Fire* with its classic good looks, is a continuous burning fire offering additional features for those appreciating the better class design. The *Rayburn Sunk Fire*, a pleasantly unobtrusive fire (with the air feed under the floor) is also available with a back boiler to heat radiators and/or domestic hot water. The *No.* 3 *Brook Fire* has an especially powerful back boiler for heating a limited number of radiators and domestic hot water.

The handsome *Marvec Convector Fire* with the 205 Convector Surround, is a highly efficient heating appliance.

All these fires are approved by the Coal Utilization Council for burning solid smokeless fuels.

The *Rayburn Room Heater* is thermostatically controlled. It will idle for at least ten hours without attention. This appliance can be supplied with or without a boiler and is a Coal Utilization Council approved appliance, burning solid smokeless fuel.

Stand No.

K.3 ASSOCIATED ELECTRICAL INDUSTRIES LIMITED, Electronic Apparatus Division, New Parks, Leicester.

Demonstrated on the stand is the AEI Dust Measuring Equipment for Power Stations and Processes. This equipment has been designed to overcome the shortcomings of methods of recording the density of smoke discharged through a duct or chimney.

The AEI system responds to dust area, but overcomes the disadvantage of optical methods, whereby flue gas velocity affects the indication, by automatically taking into account the product of particle number, velocity and area. This is achieved by providing the continuously flowing sample of gas with a corona environment, where all solid particles become electrically charged. The charge is proportional to the particle surface area.

The charge on the particles collected thereby form a current potential proportional to particle number, area, and flow velocity.

This current, after amplification, is used to either indicate or record the level of pollution. A warning can be given should the pollution rate rise above some predetermined level.

When installed in a duct or chimney, the inlet of this sampling equipment is placed so that average velocity conditions are presented to it. The outlet, in the form of a conical diffuser to overcome the impedance of the equipment to the flow of the gas being sampled, is also placed in the main duct stream.

To prevent condensation of moisture in the sampling equipment, the temperature of working parts is kept above dew point.

Build-up of soot in the equipment is prevented by automatically blowing with air for a few seconds once every 20 minutes.

The equipment, being highly sensitive, will respond to particle diameters ranging down to 0·01 microns, and can monitor flue gases leaving dust arresting plant of large boilers with burdens of about 0·04 grains per cubic foot rising to 2 grains per cubic foot during soot blowing.

K7 BERRY'S ELECTRIC LIMITED, Touchbutton House, Newman Street, London, W.1.

" Fires without smoke " is the theme of the Berry's exhibit. Magicoal fires, reproducing electrically the glow and movement of burning coal or logs, offer the perfect solution to the problem of abolishing smoke without losing the delights of an open fire.

On Berry's stand will be two Magicoal fires which can be installed as fixed heaters to qualify for a grant. With them are illuminated fixed radiators, including the colour-changing Chameleon, and a magnificent period grate suitable for boardrooms or large reception rooms.

Stand No.

F2 **BOLTON'S SUPERHEATER & PIPE WORKS LTD., Stockport, Cheshire.**

This Company will show how " Bolton-Gray " Ash Blowing Equipment will safeguard infringement of the Clean Air Act, and contribute towards fuel efficiency.

The Exhibits will make it clear that the equipment can increase the output from existing boiler plant, saving manpower and money.

Details will be available of the *new* Ash Blowing System terminating with Ash Collection and Disposal Equipment.

This Company also manufactures " Bolton-Gray " sectional Superheaters, Steam Purifiers, Expansion Joints, Pipework, Coils and Stainless Steel Fabrications.

K8 **THE BOSTON MARINE AND GENERAL ENGINEERING COMPANY LIMITED, Wolverhampton.**

This subsidiary of Midland Industries Limited, has now placed on the Home and European markets the *Hoskinson Smokeless Incinerator*.

Any combustible material can be burned in the Hoskinson Incinerator without smoke or smell, including rubber, plastics, papers, sawdust and animal matter, etc.

The Incinerator is 13½ cubic feet capacity and burns up to 300 lbs. per hour. The fire door is amply dimensioned and will even admit a full size motor car tyre.

Smoke elimination is effected by the provision of a specially designed oil or gas burner, mounted at the foot of the chimney. As smoke passes through the flame it is ignited and burns completely ensuring smokeless emission from the chimney.

The Hoskinson Incinerator with its built-in Heat Exchanger provides valuable space heat from the burning of rubbish and waste. To enable space heating to be maintained when rubbish supplies are exhausted an automatic oil burner can be supplied. The burner is mounted on rails and when required is simply slid into position.

The Unit is portable and it can be installed either inside or outside a building and its location can be changed within a day. The installation is simple, speedy and inexpensive.

E1 **CANNON (G. A.) LIMITED, Deepfields, Bilston, Staffordshire.**
CANNON GasMiser Room Heater with Thermostat

It was the outstanding development of the ' Multyjet ' Hot Air Convector incorporated in the design of the GasMiser that made it possible to use gas for Continuous Room Heating at a cost you can afford. This amazingly efficient Convector with its Double Jet action ensures the minimum of heat to flue loss and the maximum of heat into the room—only the GasMiser had this feature.

Now with the introduction of the GasMinder Automatic Room Heat Control, room heating by gas becomes even more efficient and economical. A simple dial fitted to the side of the GasMiser gives a choice of 8 *room temperatures* from 50° to 85°, maintaining the temperature required automatically. If the door is opened and a cold draught cools the room, the GasMinder thermostat will automatically increase the gas consumption to restore the room temperature.

This Thermostat is fitted in the bottom of the fire, where it is affected by air at room temperature being drawn in. It does not, therefore, come into operation until the air all through the room right down to the floor, has been raised to the desired temperature. Once that temperature has been reached, the GasMinder cuts down the gas rate to the minimum required to maintain the temperature, with consequent economy in gas and consumption costs.

The GasMinder Automatic Room Heat Control is an optional additional fitment to the GasMiser, which still incorporates the range of manual adjustments that enable the Room Heater (when used without the GasMinder) to be adjusted to give just the heat required.

A2 **CENTRAL ELECTRICITY GENERATING BOARD, Winsley Street, London, W.1.**

The Central Electricity Generating Board Stand shows examples of anti-pollution equipment as used at Power Stations.

C1 and 2 **CHEMICAL CONSTRUCTION (G.B.) LIMITED, 9 Henrietta Place, London, W.1.**

Chemico are showing their well-known range of gas scrubbers at the exhibition. A complete coverage of fume and dust removal from sub-micron to plus micron range can be handled by these scrubbers.

The Chemico Cyclonic Scrubber is effective for the removal of dusts and liquid aerosols which are plus micron in size or larger; also on problems requiring an absorption action as in the removal of obnoxious odours and low concentration corrosive acid fumes.

The Chemico P-A Venturi Scrubber has proven to be an effective and economical apparatus for difficult scrubbing jobs such as removal of sub-micron dust fumes and mists.

The Chemico type S-F Venturi Scrubber is especially suitable for the removal and elimination of " hard-to-handle " sticky solids from gases. It permits recycling of heavy slurries and recovery of concentrated process materials from gases.

Chemico wet gas scrubbing equipment is the outgrowth of more than two decades of extensive development, engineering, pilot study, and field experience. To date, hundreds of Chemico scrubbers are being successfully used throughout the world in a wide range of industries for the highly efficient removal of both sub-micron and micron dusts, fumes, mists, and fogs from gas streams.

Chemico's engineering services attack gas scrubbing problems

INSTALL THE COMPLETELY *SMOKELESS* INCINERATOR

-THE "HOSKINSON"

because it

- Burns all combustible materials without *any* smoke or odour—and this means rubber, plastics, animal matter, etc.
- Burns *faster.*
- Provides free space heat.
- Is inexpensive, portable and easy to install.
- IS GUARANTEED TO DO ALL WE CLAIM.

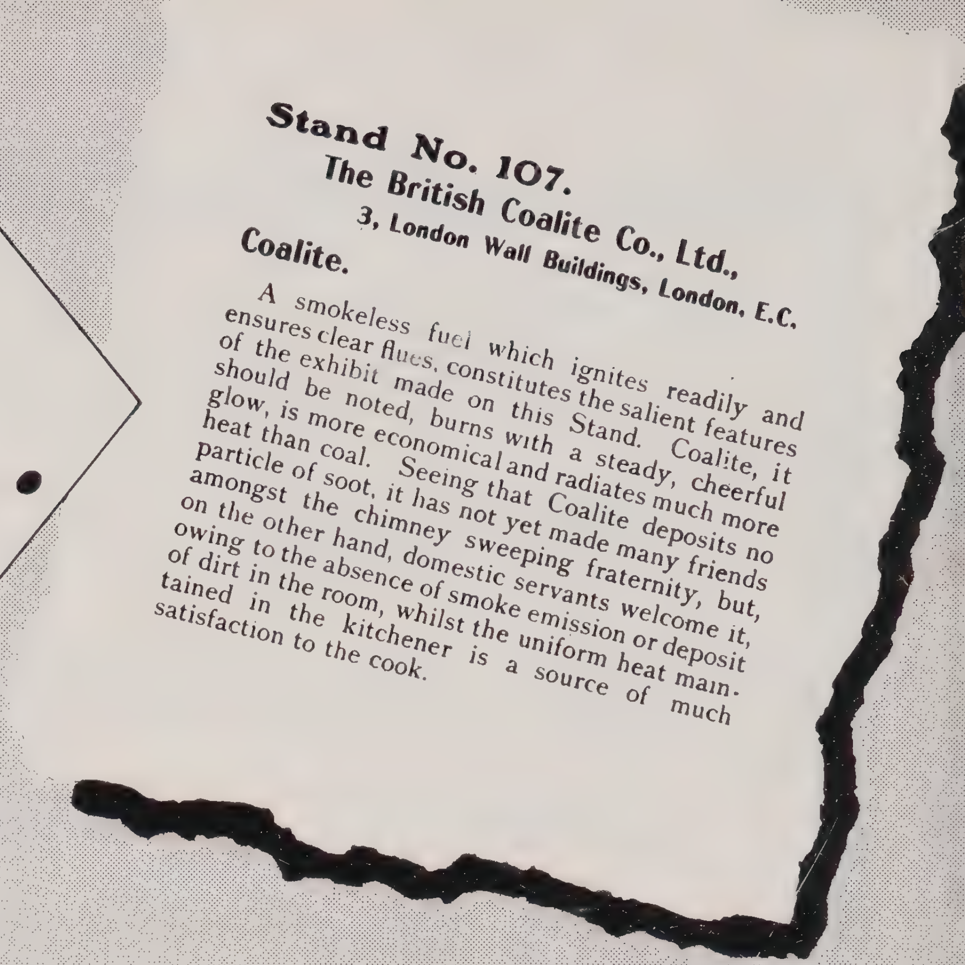
See a working demonstration of the HOSKINSON *on*
STAND No. K.8.

★ ADVICE GIVEN ON RUBBISH DISPOSAL PROBLEMS ★

BOSTON MARINE & GENERAL ENGINEERING CO. LTD.
Dept. C.A., Heath Town Works, Wolverhampton, Staffs.

Extract from the catalogue of the International Exhibition organized by the Coal Smoke Abatement Society in

1912 . .



Stand No. 107.
The British Coalite Co., Ltd.,
3, London Wall Buildings, London, E.C.

Coalite.

A smokeless fuel which ignites readily and ensures clear flues, constitutes the salient features of the exhibit made on this Stand. Coalite, it should be noted, burns with a steady, cheerful glow, is more economical and radiates much more heat than coal. Seeing that Coalite deposits no particle of soot, it has not yet made many friends amongst the chimney sweeping fraternity, but, on the other hand, domestic servants welcome it, owing to the absence of smoke emission or deposit of dirt in the room, whilst the uniform heat maintained in the kitchener is a source of much satisfaction to the cook.

FIRST —AND STILL FOREMOST

‘COALITE’

SMOKELESS COAL

‘Coalite’ smokeless coal the first successful smokeless solid fuel to be marketed in Great Britain is still the leader in its field. Economic, highly efficient, ‘Coalite’ is the ideal fuel for all domestic fires.

This year
we are on
STAND D.1
Come along and see a live ‘Coalite’ fire for yourself.

COALITE & CHEMICAL PRODUCTS LTD., CHESTERFIELD, DERBYSHIRE at the beginning—with accurate evaluation of conditions and determination of the results desired. To aid in determining specifications for the final installation, pilot size equipment can be brought directly into a plant to test actual conditions when advisable. As a result Chemico can predict efficiencies and guarantee a completely satisfactory solution to a scrubbing problem.

D1 COALITE AND CHEMICAL PRODUCTS LIMITED, P.O. Box No. 21, Chesterfield, Derbyshire.

A live " Coalite " fire can be seen on the stand. Large " Coalite " is the ideal smokeless fuel for every type of domestic grate, old or new, and openable or closeable stoves. " Coalite " Nuts, a smaller size, is equally suitable for cookers, openable or closeable stoves and hot water boilers.

" Coalite," which is very reactive, will laze or blaze according to requirements. It may be allowed to laze throughout the night or on other occasions when not required but will draw up to a cheerful blaze immediately the air regulator is opened.

" Coalite " is readily ignited in the ordinary way with paper and sticks, fire lighter or gas poker and burns cheerfully with flame giving radiant heat, maximum comfort and economy.

" Coalite " is equally as suitable as best house coal for the open fire and can be obtained from all leading coal merchants.

Prices vary throughout the country according to the geographical position in relation to the works and carriage charges that are involved. It is sometimes said that " Coalite " is expensive and whilst it may be true when this is considered initially in terms of shillings per hundredweight, the important point is that one buys by weight and consumes by volume. As " Coalite " all of which burns away without risk of flying pieces, is of greater volume than coal, it is cheapest in the long run.

It is most important to note that " Coalite " will burn satisfactorily in any type of grate or appliance without the expense of alteration.

E4 to 7 COAL UTILISATION COUNCIL, 3 Upper Belgrave Street, London, S.W.1, and at: Aberdeen, Birmingham, Bristol, Cambridge, Cardiff, Edinburgh, Glasgow, Leeds, Manchester, Newcastle-upon-Tyne, Nottingham, Plymouth, Reading and Tunbridge Wells.

The Coal Utilisation Council is a non-commercial organization founded in 1932. It is concerned with promoting the efficient domestic use of all solid fuels. In existing or proposed smoke control areas the Council's policy is aimed at the retention of the domestic market for solid fuel, either by the smokeless burning of coal, where this is possible—for example by means of mechanical stokers in blocks of flats, offices, etc.—or otherwise by the domestic use of smokeless solid fuels.

The Memorandum on Smoke Control Areas, published by the

Ministry of Housing and Local Government in connection with the Clean Air Act, quotes the C.U.C. as one of the organizations from which local authorities, contemplating the establishment of Smoke Control Areas, may obtain advice and assistance.

The exhibit explains the ways in which the Council can be of service to local Authorities that are setting up Smoke Control Areas, under the following headings:

Publications: The various publications issued by the Council which are available to local authorities are displayed. These include the List of Approved Domestic Solid Fuel Appliances (published jointly with the Solid Smokeless Fuels Federation) from which solid fuel burning appliances for replacement in Smoke Control Areas must be chosen.

Training Courses: The Ministry of Housing and Local Government Memorandum on Smoke Control Areas says that local authorities should ensure that new solid fuel appliances have been correctly installed in accordance with the methods recommended by the Coal Utilisation Council.

The training courses which the council holds for builders, appliance distributors, which are available to public health inspectors and other local government officials, are described.

Exhibitions and Publicity: The stand illustrates the various ways in which the Council, with its manifold resources, is able to help local authorities in proposed Smoke Control Areas by means of exhibitions of various types, adapted to suit local conditions, advertising and leaflets.

Technical Services: The technical services of the Council are available to any local authority in connection with the domestic use of solid fuel in Smoke Control Areas, and technical officers of the Council will be on duty on the stand.

H6 COMBUSTION EQUIPMENT LTD., 61 Belsize Lane, London, N.W.3.

Cory Grit Arrester: A low draught loss collector designed to collect grit in the range down to 76 microns. It is very adaptable and can be fitted at the top or near the base of a steel chimney stack or in a by-pass duct leading into a brick or steel chimney stack. It can also be used effectively to collect oil smuts from a brick chimney.

Mark IV Furnace Baffle: A special arrangement of firebrick for the flues of shell type boilers designed to improve combustion. Its main effects are increased CO_2 percentages and reduced side flue temperatures. It is also very effective in reducing flue dust deposits in the tubes of Lancashire boilers and in the combustion chambers of Economic boilers. It can be of advantage with both liquid and solid fuel.

Flue Dust Blower: This is a simple blower to be fitted at the base of the bridge and, used in conjunction with the Furnace

Baffle mentioned above, can give a completely clean flue tube in a Lancashire boiler.

Airlock Damper: This is a gas-tight Damper designed to reduce heat losses during stand-by periods on Lancashire and Economic boilers.

J2 and 3 CROSTHWAITE FURNACES & SCRIVEN MACHINE TOOLS LIMITED, York Street Ironworks, Leeds, 9.

On display is the " Clair " Combustion Unit, a gravity-fed, self-cleaning steam boiler designed to burn a wide range of fuels smokelessly, and to meet the full requirements of the Clean Air Act. This unit, which is suitable for Shell type, small water tube and sectional heating boilers, is fitted with variable speed drive and spring-loaded ram to ensure positive feed. A fan-forced draught is also included which is effective throughout the length and breadth of the grate. The unit is capable of producing full boiler ratings, can be fired in an emergency and can also be bank fired.

J1 DAVIDSON & CO., LIMITED, Sirocco Engineering Works, Belfast 5, Northern Ireland. Local Branch: National Employers' House, Quebec Street, Leeds, 1.

The Company's manufactures cover a wide range both in the field of Fan Engineering and Machinery for Tea Estate Factories, but the products displayed at this Exhibition have been specially confined to the general theme of efficient combustion and with particular emphasis on the aspect of the Clean Air Act.

The exhibits shown are scale models of the Company's products and clearly demonstrate the operation and manner of installation of the well-known " Sirocco " " R " Type Dust Collector and the Shunt Suction Type Collector, both models with associated " Sirocco " Induced Draught Fans.

In addition, there is displayed an illustration of the fall-out of dust from a typical factory chimney which is not serviced by a Dust Collector.

Samples are shown of the actual dust collected by " Sirocco " equipment in many installations throughout the country.

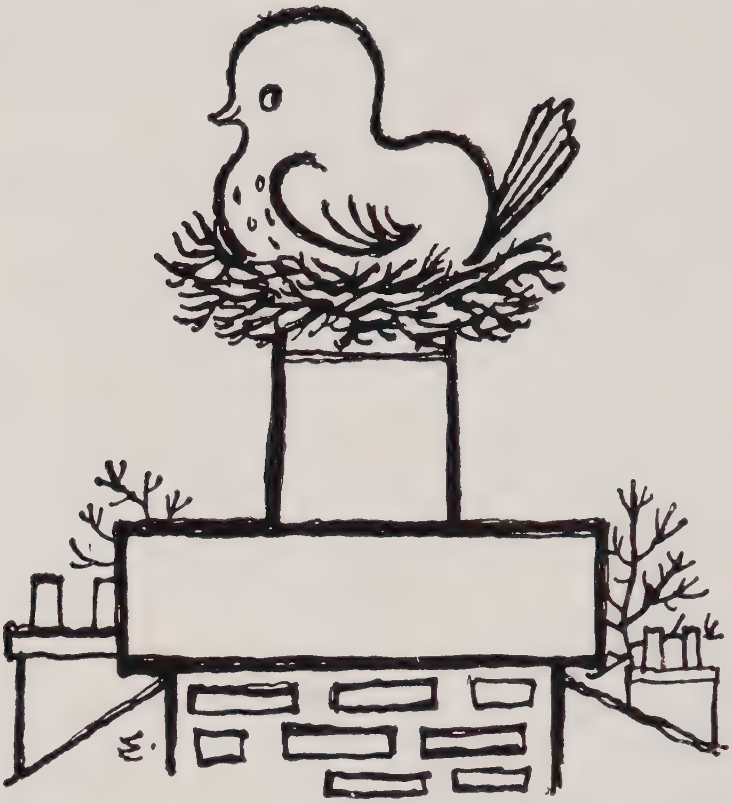
Literature is available illustrating and describing the Company's products appropriate to this Exhibition and in addition, the services of our trained engineers are available in a consulting capacity.

A1 DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH, Warren Spring Laboratory.

Material will be presented to show that the smoke concentration at any point is normally determined by the density of population and the domestic coal consumption in the immediate neighbourhood.

A new portable instrument will be shown for the determina-

As electricity takes over



so does clean air

No fuel is so clean as electricity. No fuel makes a bigger contribution to the Clean Air Act. And no fuel has a bigger future in all our lives.

Electric floor warming is cheap to run and cheap to install in new buildings: it needs no chimneys, pipes nor radiators. Electric water heaters and cookers too are the most economical to run nowadays—and they're so clean that walls and paintwork stay like new.

With an eye to the future. There will always be abundant supplies of electricity. Now we can generate it from nuclear energy. Everyone should be thankful for electricity—and for the clean air it brings. Visit the Electricity Stand for facts and figures about all-electric homes.

The future is electric

ELECTRICAL DEVELOPMENT ASSOCIATION
2 Savoy Hill, London W.C.2. Tel: *TEMple Bar 9434*

11559A

tion of smoke and sulphur dioxide without the use of external power supplies. This is proving invaluable for special surveys.

The large effect of traffic in towns on the smoke concentration in congested streets has been demonstrated by its use.

F1 DISTRICT BANK LIMITED, 13 Spring Gardens, Manchester, 2.

N1 to 3 DUNEDIN ENGINEERING CO. LTD., 73/75 Mortimer Street, London, W.1.

Dunedin System Maintenance Equipment: Dunedin System equipment, details of which can be seen on Stands N1, 2 and 3, has been specially designed to ensure first class operation in diesel engines.

Inefficiency in the combustion system of a diesel engine soon shows itself in unnecessary exhaust smoke emission. This bad exhaust can be caused by a variety of reasons but is usually due to faulty or incorrectly adjusted fuel injection components, following incomplete maintenance.

The obvious practical answer to this problem is the use of up-to-date, efficient, simple and practical fault diagnosis, testing and tuning instruments provided by Dunedin. Complete combustion is then ensured. The whole problem of the disposal of unburnt exhaust is clearly quite secondary to the question of obtaining complete combustion of the fuel in the first place.

The instruments in question are used and approved by leading diesel engine manufacturers and are in use in service in over 100 countries.

Dunedin is Britain's answer to unnecessary pollution by diesel vehicles and it should be noted that when in proper trim the diesel engine represents a most complete form of combustion, besides offering the user immense power with the minimum fuel consumption.

Dunedin fuel injection testing instruments are unique and manufactured by no other company anywhere.

H1 and 3 ELECTRICAL DEVELOPMENT ASSOCIATION, 2 Savoy Hill, London, W.C.2.

This exhibit illustrates some of the many ways in which electricity is contributing to the achievement of clearer skies over Britain.

Visitors will see how electricity, made even more plentiful by the advent of nuclear energy provides low cost light, heat and power for homes and factories and how older buildings can be brought up to date with specially designed electrical apparatus.

Electric underfloor heating is fully covered and examples of other forms of electric heating which rank for a grant are dealt with.

E.D.A. publications, including " Nuclear Power to Clear the Air," " The Clean Air Act and You " and the synopsis of the film

"The Future is Electric" are freely available from the E.D.A. exhibit where a friendly and experienced staff are ready to answer your questions.

G5 **FILTER-HEAT LIMITED, 33 Market Square, Rugeley, Staffs.**

This company, which is a subsidiary of the well-known and old-established engineering firm of Sutcliffe, Speakman and Company Limited, Leigh, Lancashire—themselves experts in specialized methods of air filtration—concentrates solely on the design and supply of plants for dust collection and nuisance removal.

To the original Filter-Heat patented Wet Dust Collector has now been added an extensive range of dust exhausting equipment including Cyclones, Cloth Filters, Reverse Jet Filters, Cupola Grit and Spark Arresters and Paint Overspray Collection Plant. Sutcliffe Speakman Active Carbon Filters are available also, of course.

On the Stand can be seen models and illustrations of the range of plant offered by this young and active company. Attention is drawn in particular to their Grit and Spark Arrester for application to foundry cupolas (a further development of their patented Wet Collector) and to their Reverse Jet Collector (the company's most recent and highly successful development).

R3 **FUEL EFFICIENCY (ARROW PRESS LTD.), 1 Stamford Street, London, S.E.1.**

Copies of "Fuel Efficiency" are displayed and available on the Stand.

Information is also available concerning the 1960 Fuel Efficiency Register of Industrial Heating—a completely new handbook incorporating a descriptive sectionalized list of plant and equipment.

"Fuel Efficiency" is a monthly publication whose chief concern is to promote the use and clean burning of the most appropriate fuel and equipment for each heating purpose. Its readers include plant engineers, fuel industry officials, architects, builders, local government officials and fuel consultants. The users of 80 per cent. of industrial fuel consumed in this country are represented by its industrial readership.

"Fuel Efficiency" is published at 30s. per annum by Arrow Press Limited, the publishers of "Industrial Finishing" and "Ceramics."

F6 and 7 **GENERAL ELECTRIC COMPANY, Magnet House, Kingsway, London, W.C.2.**

The G.E.C. stand shows a comprehensive display of electrical space heating equipment, completely smoke and fume free, for industrial, commercial and public buildings.

To take advantage of cheap off-peak tariffs the G.E.C. designed the Nightstor heater which stores heat at night for use the following day. These heaters consist of a sheet steel bronze finished outer casing in which centrally placed element panels are surrounded by heat storage blocks. There are six models available with loadings from 1 kW to 3 kW of which the 3 kW and 1½ kW models are shown.

In self-service stores, libraries and other situations where floor space is limited wall mounting fan heaters are ideal. A display of these includes the attractively styled 3 kW and 5 kW models. Three control units for these fan heaters, that enable the fan only to be used in warm weather are also displayed, one incorporating a thermostat.

Often in churches, lobbies and similar places a large volume of warm air is required at low level. To illustrate heaters for this purpose a 10 kW fan heater housed in an attractive styled sheet steel case is shown.

Many buildings are only used intermittently or they may be of such light construction that heat losses are considerable. In each case the answer to the problem is the Twin-Zone Overhead Radiant heater which warms the person rather than the air around him and which will be on view on the G.E.C. stand. Heat, which is felt almost immediately after switching on, can be concentrated exactly where it is needed, thus affording considerable saving in running costs. By a simple adjustment to the reflector the heat can be concentrated over isolated sections of large buildings such as loading bays and hangars or over a wider area for complete heating installations in churches, village halls and similar buildings.

For converting out of date solid fuel fire systems to completely clean electrical systems, a range of hot water circulators has been developed and one example is shown.

The display is completed by a selection of smaller items of heating equipment including tubular heaters loaded at 60W per foot and obtainable in lengths up to 15 ft. and in four banks.

L1 and 2 **GRAHAMSTON IRON CO. LTD., P.O. Box No. 5, Falkirk, Stirlingshire.**

This Company are displaying a variety of room and water heating appliances, all of which are eminently suitable for inclusion in Smoke Control Areas or Smokeless Zones. They are all included in the Approved List of Domestic Solid Fuel-burning Appliances published jointly by the Coal Utilisation Council and the Solid Smokeless Fuels Federation. Most of their appliances are also included in the 6th Edition of the Coke-burning Appliances Handbook issued by the Gas Council. For easy lighting of smokeless fuels gas ignition tubes are available on all their continuous-burning fires.

1. *Queen Under-Floor Draught Fire* with Raised Front and Self-contained Boiler Unit. This appliance is designed to supply the domestic hot water from a 25/30 gallon cylinder, and in addition it will adequately heat a living room of average dimen-

sions. An extension plate is available for overnight burning on smokeless fuels. Can also be supplied without S.C. Boiler Unit.

2. *Queen-Star Continuous-Burning Fire.* This is the Company's latest drop-front fire, which can be used with or without a boiler and will provide both room heating and water heating services on the minimum of fuel. It will burn overnight on most fuels, including smokeless.

3. *Queenette Continuous-Burning Fire.* This fire has a low front and will provide the same services as the Queen-Star. An extension plate is available for overnight burning on smokeless fuels.

4. *Queen Drop-Front Fire.* This fire is displayed in its latest form. It incorporates all the features of the Queen-Star and Queenette Fires.

5. *The Queen Fire* is also shown with a large back boiler, which is capable of supplying heat to two or three radiators in addition to supplying the normal domestic requirements and room heating. This appliance should be used in conjunction with an indirect hot water cylinder.

6. *Queen-Heater.* This open and close stove is of exceptionally pleasing appearance, and won a Council of Industrial Design Award in 1959. It can be supplied with or without a boiler and provides adequate room and water heating.

All of this Company's appliances are available in an attractive range of vitreous and lustre enamel finishes, and their various continuous-burning fires can be supplied with chrome steel bottom-grates on request.

G3 and 4 **E. GREEN & SON LIMITED, Economiser Works, Wakefield.**

The main features on the stand will be full scale exhibits of three main products of the Company, showing the interest and care which has been taken in the production of equipment to meet the requirements of the Clean Air Act.

The *Paraclone Dust Collector* is cut away to show the cleaning device which, allied to the unique form of cell construction, contributes largely to the high and sustained collecting efficiency obtained on the most difficult dusts. Among typical installations for this most advanced of Dust Collectors is its use in boiler plants, cement plants, iron and steel works and foundries. The construction of the Paraclone Dust Collector is such that it is readily and conveniently installed into the flue gas ducting and occupies the minimum of space.

The *S.K.D. Centrifugal Dust Collector* which is designed principally to meet the needs of the smaller shell type boiler installation, represents the ideal answer to the Collector space and cost problem. Maintaining a practically constant efficiency characteristic down to approximately 35 per cent. of full load by virtue of its built-in secondary circuit, it will operate even on oil smut at efficiencies approaching 75 per cent. On stoker-fired dust, efficiency is normally in the high nineties.

On the stand too, is shown the operation of a dust classifier by one of the Company's dust engineers, to illustrate the care with which each individual dust collecting problem is approached. Typical examples of classified dust will be available, and the machine will be operated for brief periods to demonstrate the manner in which the eight grades of dust are obtained.

Typifying the range of industrial fans is a *Series* 500 *Fan*, the smallest made by the Company. This fan has a forward curved multiblade impeller and is normally supplied for I.D. service on shell type boilers.

E. Green & Son Limited are not on this occasion showing their economisers which have been manufactured by the Company for over 100 years, but the staff will be available to give information on all the products manufactured by this Company if required.

G1 HARGREAVES (WEST RIDING) LTD., Bowcliffe Hall, Bramham, Boston Spa, Yorkshire.

The Hargreaves Group of Companies are distributors of solid and liquid fuels over a wide area of the country with offices situated throughout the North of England.

Fuels are distributed by road, rail and canal; the Group also has shipping interests.

To maintain its services to the consumer the Group has developed a comprehensive Technical Service to advise on all fuel and heating problems, industrial or domestic. Advice given on fuel selection is always impartial, and in the interests of the consumer. To further this service, at our Head Office is a modern fully equipped laboratory capable of undertaking all types of fuel analysis.

A qualified team of Chemists and Engineers staff the Technical Service and are always available to help solve your fuel problems.

Since the passing of the Clean Air Act increasing attention has been paid to the problem of smoke abatement. Many Local Authorities have taken positive steps in this matter by the formation of Smoke Control Areas. The Hargreaves Technical Service is able to provide the specialist technical knowledge to implement the Clean Air Act, and to date has been instrumental in improving boiler plant by either plant conversion or a change of fuel.

The Technical Service is at your disposal absolutely free of charge and without any obligation.

At this Exhibition many types of fuel are on display showing the full range of fuels distributed by the Hargreaves Group, together with illustrations of the Company's activities in support of cleaner air through help and advice to fuel users.

C3 and 4 HARRIS ENGINEERING COMPANY LIMITED, York Works, Browning Street, London, S.E.17.

Stand No.

G2 LESLIE HARTRIDGE LTD., 151 Great Portland Street, London, W.1.

Hartridge B.P. Smokemeter—For Diesel Engine Exhausts: A reliable scientific instrument for accurately and quickly measuring the density of diesel exhaust smoke and thereby eliminating visual errors. This machine was originally developed by the Research Laboratories of the British Petroleum Company for investigating the causes of visible smoke and has now been perfected by Leslie Hartridge Ltd. for general use.

The Smokemeter, which is portable and robust, gives an instantaneous direct reading of smoke density on a 0–100 scale. It is equally suitable for use by laboratories, factories, transport undertakings and garages, service stations, police and health authorities. It will also operate on slow and high speed engines of all sizes and can be used at night.

The Hartridge B.P. Smokemeter has been approved by the Air Pollution Panel of the British Motor Industry Research Association for research work after many thousands of hours on engine test beds and vehicles. Its principle is based on the comparison of the density of a column of smoke with a column of clean air passing through tubes which are optically and dimensionally identical. A light source and a photo electric cell are so arranged that they can both be moved together from the smoke tube to the clean air tube. A photocell is connected to a microammeter with Smoke Density Scale reading 0–100 representing percentage light absorbed. A small Blower draws in air to the clean air tube which then passes across the surfaces of the light source and photocell, thus preventing sooting of these vital surfaces.

For vehicle testing the complete unit can be carried on a bus platform, truck tailboard, or coach floor. Alternatively, the Smokemeter can be conveniently taken from engine to engine in research or production testing by means of a special Mobile Power Unit carrying a 12 volt battery with charger or a mains transformer as a ready means of keeping the light source constant.

H2 L. G. HAWKINS & CO. LTD., 30/35 Drury Lane, London, W.C.2.

L. G. Hawkins & Co. Ltd., will be exhibiting two entirely new heaters which clearly show that this firm wishes to assist our Society in its efforts for Clean Air. These are the *Florida* combined Electric Radiant/Convector beautifully designed on the most up-to-date " Slim-Line " style, with " Thermoglass " protecting the $2\frac{1}{2}$ kW element, thus ensuring complete protection against accidents through inflammable materials coming in contact with the heater.

The other new model is a really good " Coal Effect " fire which will be supplied in two finishes—gold and silver, again designed to stand on modern hearths. This will be known as the " Hawkins 800 " and will be available in 2 kW or 3 kW as required.

In addition to these, Hawkins will be showing their full range of electrical domestic appliances including such world widely known products as their " Hostess " automatic tea-makers, " Hi-Dry " electric clothes dryer and airer, " Fair-Lady " hair drying set complete with hood and stand, irons, kettles, toasters, etc.

The Hawkins non-electric products will include their range of pressure cookers (seven models) and their new " Sunray-Safeguard " oil-heater which has been produced to conform to the latest British Standards Specification 3300/1960.

Even the most exact requirements in this new specification have been exceeded by Hawkins, who have added an additional feature to their heater in the form of a Bi-Metal Thermostat which will cut off the fuel supply should, for any reason at all, the heater become overheated.

A visit to Stand No. H2 will certainly not be a waste of time.

B2 **W. C. HOLMES & CO. LTD., Turnbridge, Huddersfield.**

The Holmes' range of dust collection and control plant is one of the most extensive in the world and includes: electrical precipitators, electrical filters, bag filters, wet type dust collectors, multi-cell cyclone and cylcone dust collectors.

Holmes-Elex Electrical Precipitators: Holmes-Elex Electrical Precipitators have been specifically designed to remove extremely small particles, in the sub-micron range, from all types of carrier gas. The particles, either liquid or solid, are separated by passing the contaminated gas through a high voltage electrical discharge which imparts a negative charge to the particles and then deposits them on to collecting plates. The particles are subsequently removed from the collecting plates by various means depending on the application.

Holmes-Schneible Multi-Wash System: The Holmes-Schneible Multi-Wash System is applicable to a wide range of dust collection and control problems involving liquid and solid particles. The multi-wash collector has many advantages over other types of collector: it has an extremely high efficiency (of the order of 99 per cent. for all particles above 3–4 microns): it has a lower pressure drop than many other types of wet washers, and an absence of circuit restrictions which might cause blockages.

Holmes-Schneible Multi-Wash Collectors are unique in that they embody three well established principles of dust collection:

1. Centrifugal force in the cyclone in the lower portion of the collector throw out the heavier particles.
2. Bombardment of dust particles by a finely divided self-induced spray.
3. Contact between dust laden air and wetted plates having a large total surface area.

Holmes-Rothemuhle Multi-Cell Cyclone Dust Collectors: Holmes-Rothemuhle Multi-Cell Cyclone Dust Collectors (both reverse flow and through pass) are the answer to many of the problems involved in the collection of dust and grit particles in the higher size ranges (10 microns and above). In addition to the advantages of low installation, operating and maintenance costs, these collectors have the added advantage of space saving construction which enables them to be easily fitted into existing flue-gas ducting.

L3 **ARCHIBALD JOHNSTONE (ENGINEERS) LIMITED, Ninelands Lane, Garforth, Leeds. London Office: 60 Abbey House, Victoria Street, London, S.W.1. Cardiff Office: 22 Heol Llanishen Fach, Rhiwbina, Cardiff.**

Manufacturers of Air Preheaters, Mechanical Draught and Dust Collection Equipment.

Whilst their field of operations has hitherto been confined mainly to the Power Stations of the Central Electricity Generating Board, the wide experience gained in that field is such that invaluable assistance can be given in the problems experienced in smaller power plants.

A Technical and Testing Service is readily available equipped for carrying out tests *in situ* with a view to diagnosing combustion problems at source and making recommendations which invariably lead to improved efficiency and availability.

Prototype collectors are available for the carrying out of tests to establish the collection efficiency obtainable with samples of the actual material required to be collected.

Exhibits include an Aerofoil Bladed Fan Impeller, a " JR " Cyclone Dust Collector model and an " AJ " Automatic Dust Valve.

R2 **CHARLES KNIGHT & CO. LTD., Local Government and Law Publishers, 11-12 Bury Street, London, E.C.3.**

This stand will carry a display of forms required under the Clean Air Act, and of publications on public health law which include statutes, regulations and circulars relating to clean air.

F5 **LODGE-COTTRELL LIMITED, George Street Parade, Birmingham, 3.**

The above Company will be showing:

1. A working model of the principle of precipitation using finely atomized liquid.
2. A static model of a precipitator for the removal of dust from the gases of a pulverized fuel fired boiler, typical of those installed and used on large power stations.

In addition there will be a display of various photographs of different installations carried out by the Company in many parts of the world.

B1 **MINISTRY OF HOUSING AND LOCAL GOVERNMENT, Whitehall, London, S.W.1.**

A series of special maps show local authority programmes for smoke control in England and Wales during the next twenty years, indicating at a glance the target years for completion of programmes in the black areas where air pollution is worst.

R5 **MUNICIPAL ENGINEERING PUBLICATIONS LTD., and THE MUNICIPAL JOURNAL LTD., 3/4 Clements Inn, London, W.C.2.**

Displayed on this stand will be " Municipal Engineering," " The Municipal Journal," " The Municipal Year Book " and sundry books and publications produced by other companies within the Group.

" Municipal Engineering " caters specifically for all the technical officers of local government whose work is directed towards improving health and welfare of the community.

It is *the* weekly journal most widely read by public health inspectors and public cleansing officers. Its coverage of such matters as the control of air pollution, sanitation, food hygiene, meat inspection and slum clearance has made it essential reading for these officers.

" The Municipal Journal " each week highlights news and views on all aspects of local government affairs through co-operation with government departments, local authority associations and societies and individual councils. It keeps its readers abreast of current thought and development. Administration, finance, law, building and planning, public health, refuse disposal, sewerage and sewage treatment—these and all other aspects of local government work are continually kept under review.

Recognized as the encyclopaedia of local government and an essential work of reference, " The Municipal Year Book " contains full statistical data of all local authorities. It includes names, addresses and telephone numbers of 40,000 officers of local government and of Associations, Institutions and Societies. In all some 1,900 pages.

D4 and 5 **NATIONAL CARBONISING COMPANY LIMITED—REXCO SMOKELESS COAL, 14 Woodhouse Road, Mansfield, Notts.**

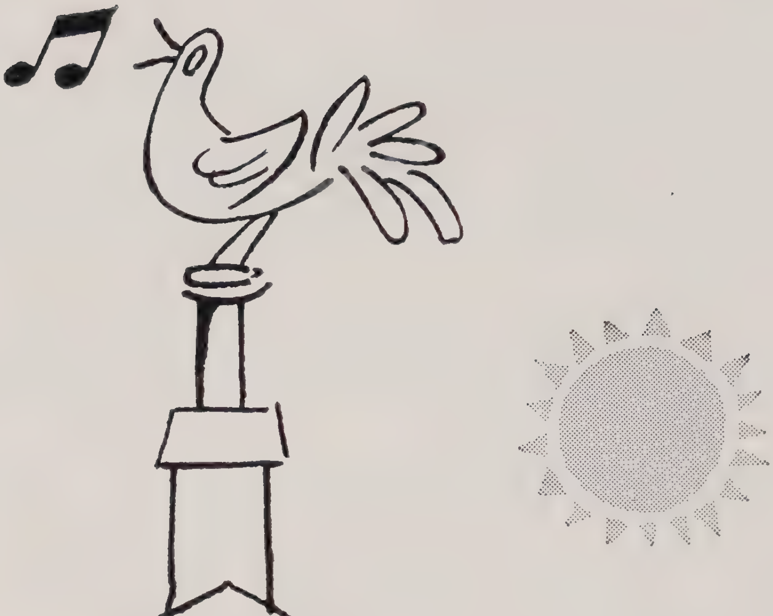
One section of the display portrays a lounge with Rexco smokeless coal burning in a convector fire.

Visitors to the stand will notice the flames and heat radiation associated with the burning of very reactive smokeless fuel. Rexco overcomes the prejudice of the public who insist on seeing a fire with a cheerful flame.

Rexco, easily lit by sticks and paper, will burn freely and without smoke, thus avoiding the necessity of fitting special grates and providing gas ignition.

The second section of the stand carries illustrations of the production and distribution of Rexco Smokeless Coal.

Newton Chambers & Company Limited are showing a selection of Redfyre solid fuel burning appliances. These include



How the National Coal Board contributes to clean air

The National Coal Board produces not only natural smokeless fuels (anthracite and Welsh dry steam coal). Its fuel technologists are continuously at work, developing new smokeless fuels that will be even hotter, cleaner and more economical than any solid fuel now available. National Coal Board smokeless fuels not only cut down dirt in the air, in the chimney and in the home. When burnt in modern appliances, they save dramatically on your fuel bills by giving far more warmth for your money.

VISIT STAND A3 AND STAND E3 AND SEE NCB SMOKELESS FUELS DEMONSTRATED

National Coal Board

the Redfyre '60' Continuous Burning Fire, and the Hearth Redfyre with under floor air feed; both are available with backboiler units, all suitable for Rexco Smokeless Coal.

Displayed in addition, will be the Redfyre Convector No. 2 which is under fire. This is an easy appliance to install giving two-way warmth by radiation and convection.

The Redfyre Magazine Boiler for hot water and radiators is also on show, and as with the other Redfyre appliances mentioned, is an approved appliance.

The Rexco and Redfyre representatives will be in attendance daily to discuss your specific requirements.

A3 and E3 **NATIONAL COAL BOARD, Hobart House, Grosvenor Place, London, S.W.1.**

The National Coal Board stand No. A3 shows the range of naturally smokeless solid fuels and manufactured smokeless solid fuels available to the domestic consumer at the present time. It will also introduce new smokeless solid fuels which will be shortly available and one of these is shown under fire on stand E3.

Also on display are the latest types of solid fuel boilers suitable for trouble free central heating, and a display on small bore forced circulation central heating illustrates how considerable savings may be made by fitting solid fuel boilers.

A model of one of the Board's new fuel plants shows the processing of new fuels on stand No. A3.

F3 **NATIONAL INDUSTRIAL FUEL EFFICIENCY SERVICE, 71 Grosvenor Street, London, W.1.**

N.I.F.E.S. Services can assist Local Authorities and Industry to implement and comply with the requirements of the Clean Air Act. Pictorial panels will illustrate this in detail.

Many Local Authorities when considering applications for prior approval of new equipment now use N.I.F.E.S. Services to provide them with the necessary technical advice.

A regular Service Agreement with N.I.F.E.S. assures industrialists that their boiler plant and equipment is properly maintained and correctly operated.

By means of the Specific Advisory Service a solution can almost always be found for smoke and grit problems.

N.I.F.E.S. Boiler Operator Training Courses prepare stokers in theory and practice for the City and Guilds Boiler Operator's Certificate Examination. This certificate ensures that the stoker is capable of operating boiler plant efficiently.

The New Stoker's Manual, a handy pocket size reference book for stokers, will be available on the stand. More than 20,500 copies have been sold during the past year and the manual acts as an introduction to the City and Guilds Certificate Course.

Stand No.

N4 NATIONAL SOCIETY FOR CLEAN AIR, Field House, Breams Buildings, London, E.C.4.

The Society's stand will feature two of the Exhibition units now available in most of the Society's Divisions. Newly prepared photographic panels and display material will be shown, and copies of publications by the Society, H.M. Government, etc., will be on sale. The Exhibition units and the new display material may be borrowed by any local authority, together with a set of notes and designs for an Exhibition Stand.

Industrialists are invited to make use of the Society's Information Service. Our Information Officer will be available and will be pleased to give all possible help.

Note:—The Conference Office is adjacent to the Society's stand at the end of the Hall.

J4 NORTH EASTERN GAS BOARD, Bridge Street, Leeds.

With the advent of the Clean Air Act empowering local authorities to enforce clean air zones, the architect and builder takes this into consideration when planning heat service for new buildings. But there are thousands of existing houses with old fashioned grates which are inefficient and unsuitable for burning smokeless fuel. Part of the North Eastern Gas Board's display, therefore, shows how different types of old-fashioned open grates and kitchen ranges can be converted to burn smokeless fuels. Appliances in this feature include an ordinary stool bottom grate, similar to many still in use in the living rooms of modern houses, the older type of cast iron or register grate still prevalent in older terrace houses, and an old-fashioned kitchen range. Each of these appliances is flanked on either side by a display showing how they can be changed to gas or coke.

In addition, there will be five " live " modern space heating appliances—two gas fires, an open coke grate, a closable coke stove, and a stool bottom grate in which will be burned " Cleanglow " the new premium grade coke which can be used in an ordinary open grate. Another exhibit shows how a " Yorkist " range can be converted to burn coke.

There will also be a gas-fired incinerator on show, which is suitable for the disposal of kitchen refuse.

H5 W. OTTWAY & CO. LTD., Orion Works, Northfield Avenue, London, W.13.

The " Telesmoke." A Telescope for checking the density of smoke under the Clean Air Act. This instrument, which has been developed in conjunction with the Fuel Research Station, Greenwich, of the Department of Scientific and Industrial Research, is manufactured under licence from The National Research Development Corporation and is designed to provide a more convenient method of measuring the smoke density, while retaining the high accuracy which can be obtained with a Ringelmann Chart.

Two types are available, the standard instrument showing an inverted image, while the prismatic monocular type shows a normal erect image.

Dust Sampling Equipment. Long Running Thermal Precipitator. National Coal Board Type 101*C.* An instrument for sampling airborne dust has been designed to operate over periods of up to eight hours. Only the respirable dust, which is selected aerodynamically from the total airborne cloud during the sampling process is collected. The selection of this is effected by drawing the dust-laden air through a horizontal duct elutriator, the action of which simulates that of the human nose and upper respiratory passages in which the removal of the largest, fastest falling particles is due to the processes of settlement and impingement. Evaluation of the sample is normally by visual Microscopy, but the method of collection employed provides a deposit well suited to bulk evaluation techniques.

The Kotze Konimeter. For testing a dusty atmosphere to determine both the number and size of dust particles contained in it. The particles are collected on a glass slide and cover an area approximately 1 millimetre. The slide is then examined under a microscope fitted with a specially graticuled eyepiece and the particles of dust counted and measured.

Students and Low Power Microscopes. Pocket Microscopes, also a selection of Measuring Magnifiers and simple optical magnifiers of various types and descriptions.

E2 **THOMAS POTTERTON LIMITED, Cavendish Works, Buckhold Road, Wandsworth, London, S.W.18.**

" Potterton " gas and oil-fired boilers are available in a wide range of sizes for central heating and hot water in a wide variety of domestic, commercial and industrial premises.

All " Potterton " boilers are made of cast-iron for long life. They are completely automatic and give a very high working efficiency. They make no smoke, dust or ash and are suitable for installation in areas covered by the Clean Air Act.

The boilers are of sectional construction though the smaller sizes are delivered completely assembled for easier installation. These " domestic " sized boilers have a smooth coating of vitreous enamel on the flueways—this helps to prevent corrosion and reduces maintenance time and costs.

R4 **PYRAMID PRESS LIMITED, 41 Streatham Hill, London, S.W.2.**

All the publications shown on the stand of Pyramid Press Ltd., have been produced completely free of cost to the Local Authorities concerned. These publications are designed to inform members of the general public not only of the general provisions of the 1956 Clean Air Act but also as far as their own smoke control areas or smokeless zone is concerned, of the provision and types of appliances and householders' obligations and other relevant information that they must know and act upon.

These books have a decided local application and, because they are supplied free of cost to the Authority, can be supplied and distributed in adequate numbers.

Your enquiries and suggestions regarding the application of their publishing facilities to your own publicity problems, are cordially invited.

M7 and 8 RADIATION GROUP SALES LTD., Solid Fuel Division, 255 North Circular Road, London, N.W.10.

For many years the basic design requirement for Radiation solid fuel appliances has been efficient operation on smokeless fuels and the Radiation Reseach Laboratories have pioneered many important developments in this field.

The Parkray family of smokeless solid fuel appliances includes open-fire convectors with and without back-boilers, closeable room heaters, independent domestic boilers and open-fire inset grates. To typify the full range, the exhibit includes:

Parkray 2 freestanding open-fire convector and water heater, in an unusual setting, the hot water supply being used for radiators in a small central heating system.

Parkray 10 boiler flue set—the cheapest form of space and water heating—which incorporates the Parkray " Clean Air " fire.

Parkray 6 open-fire convector and water heater, ingeniously designed to divide into three main sections (including a pre-cast concrete convection chamber) for easy installation in existing fireplace surrounds.

Parkray 60—water heating version of the attractive " slim " Parkray 30 room heater, with clear glass doors.

Parkray " Clean Air " fire, with interchangeable front, simplifying choice or change of colour finish.

R1 SANIGUARD APPLIANCES LIMITED, 62 London Wall, London, E.C.2.

The Barrywald Safety Sanitary Incinerator: The Barrywald on display is a development from the original design produced over fifteen years ago being an advancement on all previous models that have won high acclaim from many thousands of different establishments for the improvement in hygiene achieved for their intended purpose.

Newest developments have produced a higher rate of disposal for a lesser running cost thus making this appliance more attractive from every point of view.

The electrical loading is now set at 1kW and all components are fully guaranteed for one year and the appliance is backed up by a fully competent service organization which can carry out its efficient activity in all parts of the country.

The size of the Barrywald Incinerator is now 19″ x 18″ x 10″ and its weight is approximately 50 lbs.; for new applications and advice regarding the installation, which is a simple matter under normal circumstances, please enquire at the Stand.

D3 SHELL-MEX AND B.P. LTD., Shell-Mex House, Strand, London, W.C.2.

Being a Good Neighbour: Approval of plans providing for the construction of new chimneys depends upon the Local Authority being satisfied that any chimneys shown are adequate to ensure that the emission of grit dust and gases shall not become prejudicial to health or a nuisance.

Determination of a suitable height for such chimneys must take into account surrounding buildings and topography. In many cases this is extremely difficult, and where a large plant is under consideration the only satisfactory determination of chimney and roof layout may be as a result of wind tunnel tests.

In the case of the new offices for the Shell International Petroleum Company Limited, on the South Bank site, a model was produced and tested in a wind tunnel at the National Physical Laboratory. The tests showed that satisfactory dispersion would only be obtained, together with an acceptable appearance, if the roof contours were modified, and minima set for the projection of the stack from the roof and the velocity of efflux from the stack.

Whilst such work would normally be outside the scope of Local Authority activities, these methods can be applied by industrial and commercial undertakings where chimney size and siting is in doubt, and the plant is of sufficient size to warrant the expenditure.

On the stand of Shell-Mex and B.P. Ltd., may be seen the method used for such wind tunnel tests, and information as to the results which may be obtained.

Information on all aspects of oil firing will be available and staff will be very pleased to discuss any queries arising from the use of fuel oil in any part of the country.

A considerable amount of literature on oil fuels and their application is available from Shell-Mex and B.P. Ltd., and requests for booklets and reprints will be welcomed on the stand.

F4 SIMON-CARVES LIMITED, Cheadle Heath, Stockport.

The Precipitator Division of Simon-Carves Ltd. has been making substantial progress in the iron and steel industry. Already they have two precipitators working on oxygen steel furnaces, and a static model based on the second unit is on display. This type of construction will be used on contracts placed with Simon-Carves Ltd. for sinter plant and L.D. converter gas cleaning. A special brochure covering processes in the iron and steel industry is available.

Also on show is an animated diagram showing the basic

ELECTROSTATIC
PRECIPITATORS
& MECHANICAL PRE-COLLECTORS

Complete Gas Cleaning Plant

for a 550 MW boiler at

THORPE MARSH

AND

two 350 MW boilers at

DRAKELOW 'C'

will be

STURTEVANT

Sturtevant
CLEAN AIR

STURTEVANT ENGINEERING CO. LTD., SOUTHERN HOUSE, CANNON STREET, LONDON, E.C.4

AUSTRALIA: STURTEVANT ENGINEERING CO. (AUSTRALASIA) LTD., 400 SUSSEX STREET, SYDNEY, N.S.W.

principle of electro-precipitation; cut-away perspective drawings and photographs of actual installations complete the exhibits.

Literature can be obtained dealing with the process of electro-precipitation as applied to the chemical industry and other industries.

Simon-Carves Ltd. have unique resources for research and development and also offer to carry out integrated contracts, with treatment, collection, handling and disposal of atmospheric pollutants as well as associated civil work.

D2 **SOLID SMOKELESS FUELS FEDERATION, 74 Grosvenor Street, London, W.1.**

Prominently displayed will be details and photographs of the services available, at no charge, to Local Authorities in support of their proposals for establishment of Smoke Control Areas. These services include the provision of both fixed and mobile exhibitions staffed by trained technical demonstrators, and also smaller display units suitable for the foyers of Town Halls, Health Departments etc., together with a wide range of leaflets suitable for public distribution.

Also displayed will be two approved appliances burning solid smokeless fuels, and a display of the authorised solid smokeless fuels.

The stand staff will be pleased to advise on use of the exhibition materials and general methods of publicity in support of Smoke Control Areas.

A4 **STURTEVANT ENGINEERING CO. LTD., Southern House, Cannon Street, London, E.C.4.**

The removal of grits, dusts, smokes and fumes from gases discharged to atmosphere from industrial undertakings and processes is now a matter of international importance and is receiving in the United Kingdom the serious attention of the appropriate Government authorities. Atmospheric pollution caused by these contaminations are costly hazards to public health and to general welfare, and an obligation is placed upon management by the requirements of the Clean Air Act to take the necessary action to prevent these elements of pollution being discharged to the air we breathe.

The choice of the most efficient and economically good equipment for the removal of these pollutants at source is best achieved by the application of specialized knowledge acquired by long experience and backed by continuous experiment and study of such problems. By this means the Sturtevant Companies have become well fitted to deal with gas cleaning and atmospheric pollution removal problems. They design, manufacture and supply all types of gas cleaning and dust arresting equipment including electrostatic precipitators, mechanical collectors of various types, high efficiency cyclones, textile filters and several designs of water-washed scrubbers.

Sturtevant plants, apparatus and equipment for gas cleaning and air filtration purposes are in use in most countries in the world, many similar to the models and units exhibited. These include:

Sturtevant Electrostatic Precipitators for cleaning industrial gases emanating from power stations, cement works, metallurgical, steel and chemical works, for which the efficiency of the collection of entrained dust, smoke and fumes is often specified and guaranteed at 99·3 per cent.

Precipitron Electrostatic Air Filters similar to the unit exhibited are treating millions of cubic feet of air per minute for the removal of particulate matter in factory, offices and laboratories.

Sturtevant " Fleetway " Air Filters for use alone or in conjunction with Precipitron cells for the complete filtration of air—removing all particles down to 1/100th of a micron at an efficiency of 99·95 per cent.

Sturtevant Newgate Collectors designed to arrest the comparatively coarse grits emitted by small and medium sized boilers. It is a mechanical draught fan combined with a primary collector and secondary cyclone collector.

Sturtevant Ludgate Mechanical Dust Collectors are ideal for use alone in any boiler flue system, or as pre-collectors combined with electrostatic precipitators giving good dust-arresting efficiencies over a wide range of operating conditions.

Sturtevant High-Efficiency Cyclones designed on fundamental aerodynamic principles yield remarkably high dust collecting efficiencies.

Sturtevant Scrubbers available in a variety of designs and several types for the wet arresting of inflammable or explosive dusts and objectionable or poisonous mists and fumes.

Sturtevant plant cleans many millions of cubic feet of air every minute; it has done so for many years and will continue to do so, for Sturtevant means Clean Air.

K6 **THERMODUCT LTD., Viaduct Works, Kirkstall Road, Leeds 4.**

Thermoduct Ltd. and their associate company HVE (Electric) Ltd. are featuring their well-known electric floor heating system in their display, which includes a full scale model of a typical installation and photographs of a few of their many successful installations in houses, flats, offices, churches, department stores, etc. Apart from its lower cost, which is of immediate interest to anyone, the outstanding advantage of the Thermoduct system is that *every cable can be withdrawn* at will, thus enabling maintenance to be carried out with complete ease and without disturbing the floor surface.

The Thermoduct system provides an economical and efficient means of heating a building; it is easy to install and has a life equal to that of the building. Its installation eliminates the costs of fuel store, boilerhouse and labour in constant stoking, maintenance, etc. . . . and also eliminates all the grit, grime and smoke associated with traditional heating methods. Basically the system is a series of heated ducts which are preformed as the concrete floor is laid; there are only five main components: cable, troughing, connectors, thermostats and control panel. Each installation is individually planned for maximum operating efficiency, but as a very rough guide it can be taken that domestic installations cost 4s. 6d. per square foot and large area installations 3s. 6d. per square foot approximately.

The company also undertakes the conversion of existing boiler heating plant to electric power, and other specialist divisions produce electrode hot water boilers, circulator boilers, electric panel heaters and fan heaters for industrial or domestic use, and electric steam cleaners. Descriptive leaflets are available on request.

K2 TILGHMAN'S LIMITED, Broadheath, Altrincham, Cheshire.

Tilghman's Limited who specialize in the design, manufacture and installation of high-efficiency dust collecting equipment, have made considerable progress in the last few years on the use of fabric Dust Collectors in fields normally well out of their range. By using synthetic fabrics and modern design techniques, Collectors for continuous and automatic operation are now available, and proving exceedingly popular due to the simplicity of operation and high collecting efficiency. Normally there is no visible discharge to the atmosphere even when handling such fine fumes as omitted from oxygen steelmaking furnaces.

Considerable progress has been made on plants from electric arc furnaces and oxygen steelmaking plants. Control at the furnaces is achieved either by a specially designed hood or by direct extraction from the furnace itself. Full details of these types of plants are available on their stand.

Also a new illustrated brochure, showing a full range of products in twenty-eight different industries will be made available on their stand.

K1 THE WOMEN'S ADVISORY COUNCIL ON SOLID FUEL, 18 South Molton Street, London, W.1.

The Women's Advisory Council on Solid Fuel wishes to draw the attention of delegates to the service which can be made available in proposed smoke control areas to which reference was made in the recent Circular 28/60, published by the Ministry of Housing and Local Government.

Women's Meetings can be organized and training courses in the operation of modern appliances and in the use of smokeless fuels can be arranged for groups of women concerned with home visiting—such as W.V.S., health visitors and home helps.

Special instructions can be given through Darby and Joan clubs and demonstrations can be arranged for groups of old people

The Women's Advisory Council—*concluded*

in suitable houses and flats.

The Council's leaflet "The Clean Air Act and the Housewife" has been revised and reprinted.

Delegates are invited to ask for details of the Advisory Service and about free supplies of the leaflet.

Mrs. E. M. Charlton and Miss R. R. Scott, the Council's North Eastern and Northern Regional Organizers, will be in attendance at the Council's Stand.

INTERNATIONAL CLEAN AIR CONFERENCE 1959

The Proceedings of the Conference have now been published in book form.

Cloth bound and cased
Quarto: 290 pages.

The contents include the 78 Papers presented, the Rapporteurs' Reviews, Discussions and Replies. Indexes to authors and other speakers and to subject matter.

30s. net
(add 2s. 6d. for postage and packing)

This volume will be on sale at the Society's Bookstall at the Harrogate Exhibition, together with other Clean Air publications of the Society, H.M. Stationery Office, etc.

Somebody doesn't know about **BOLTON-GRAY ASH BLOWING EQUIPMENT**

—He should visit Stand No. F2 and discover why it offers:-

- *Automatic control of stack emission*
- *Clean flues—maximum heat transfer*
- *Increased efficiency—coal saving*
- *NO SHUT-DOWNS for flue cleaning*
- *Easy collection and disposal of ash*

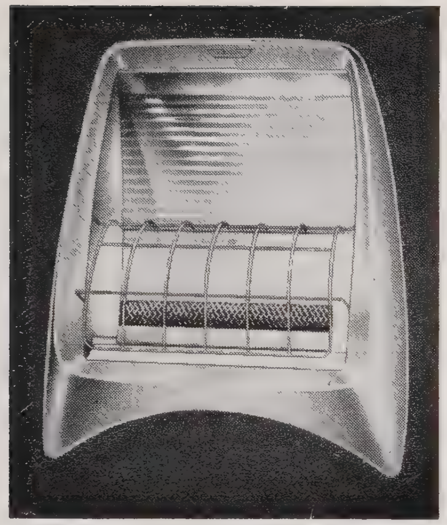
Bolton's
OF STOCKPORT

BOLTON'S SUPERHEATER & PIPE WORKS LTD
STOCKPORT. *Tel: STOCKPORT 3604*

BS 185

Firelighting for Smokeless Zones

CALOR GAS



PORTABLE POKER

Up-to-date Calor gas fires like this portable Cannon model bring the luxury of clean and speedy warmth to even the coldest rooms.

. . . .

The Calor Portable Gas Poker, worked from the handy Mark 10 cylinder, is the modern, clean and quick way to light your fires.

. . . .

Calor Gas also gives you cooking, water heating and refrigeration anywhere. *Find out more on a visit to*

STAND 16

CALOR GAS (DISTRIBUTING) CO. LTD., 178-202 GREAT PORTLAND STREET, LONDON, W.1

For Brighter, Warmer Homes in Smokeless Zones

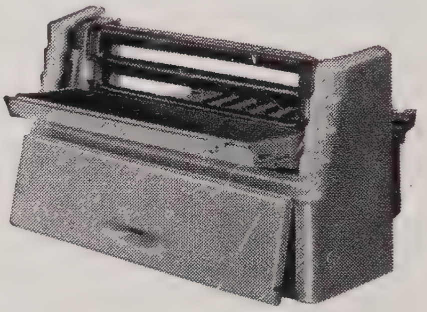
QUEEN-HEATER

Design of the Year Award Winner 1959

Winner of a Design Centre Award as one of the 16 products of outstanding design chosen from 3,000 articles displayed at the Design Centre during 1958. In a range of four colours. Boiler model available. Tested and approved by Ministry of Power and Good Housekeeping Institute. Will burn all solid fuels.

Price from £22.

QUEEN No. 51C (D.F.) Drop-Front FIRE



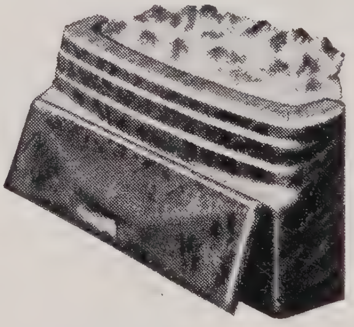
This inexpensive all-night burning fire cuts fuel bills and saves the trouble of kindling each morning. In sizes to fit and colours to match your present fireplace.

Price from £4 17s.

QUEEN-STAR Drop-Front FIRE

The QUEEN-STAR is the very latest Drop-Front continuous burning fire. It will burn all solid fuels including smokeless and is particularly suitable for smoke control areas. Fully tested and officially approved. In colours to tone with your present fireplace.

Prices from as little as £4 6s.



QUEENETTE Low Front FIRE

The low-front "Queenette" fire is an efficient, moderately-priced and economical continuous-burning fire. Made to suit most standard fireplaces and is available in Vitreous and Lustre Enamel Finishes. Price from £3 5s.

All these Appliances meet the requirements of the "Clean Air" Act and are most suitable for installation in Smokeless Zones. These types can burn Smokeless Fuels.

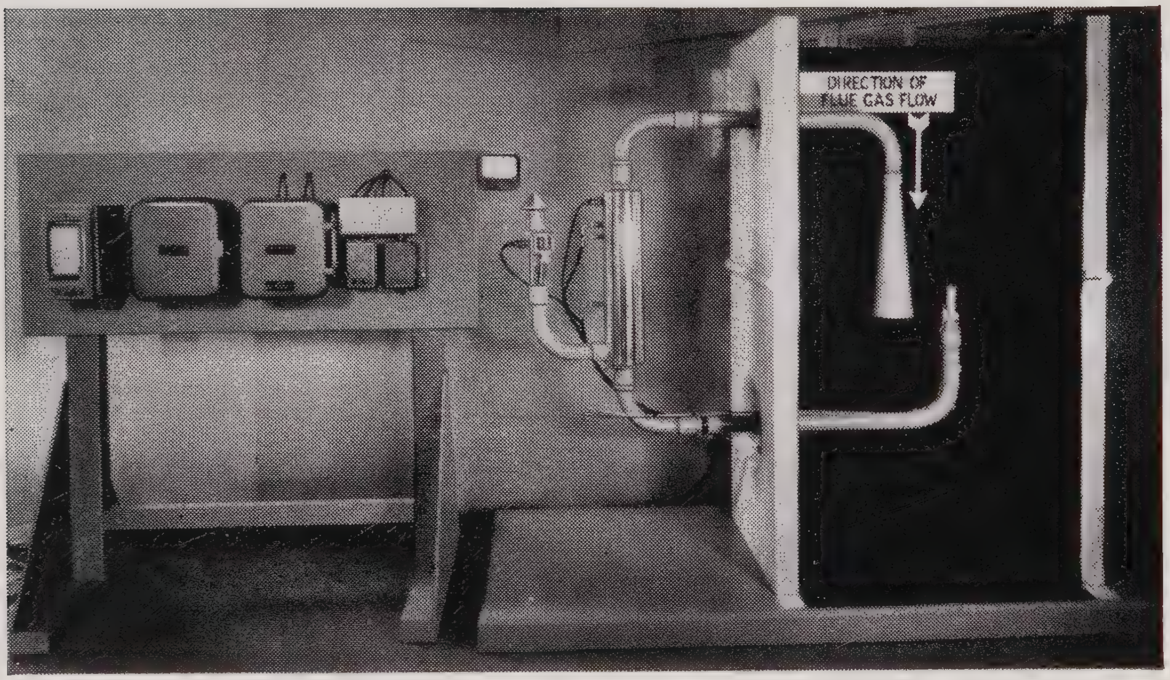
Full details on request from the Manufacturers :

Grahamston Iron Co. Ltd. · P.O. Box No. 5 · Falkirk · Stirlingshire

AEI

DUST MEASURING EQUIPMENT

for power station and
industrial applications



VISIT STAND NO. K3

Associated Electrical Industries Limited
Electronic Apparatus Division
NEW PARKS, LEICESTER

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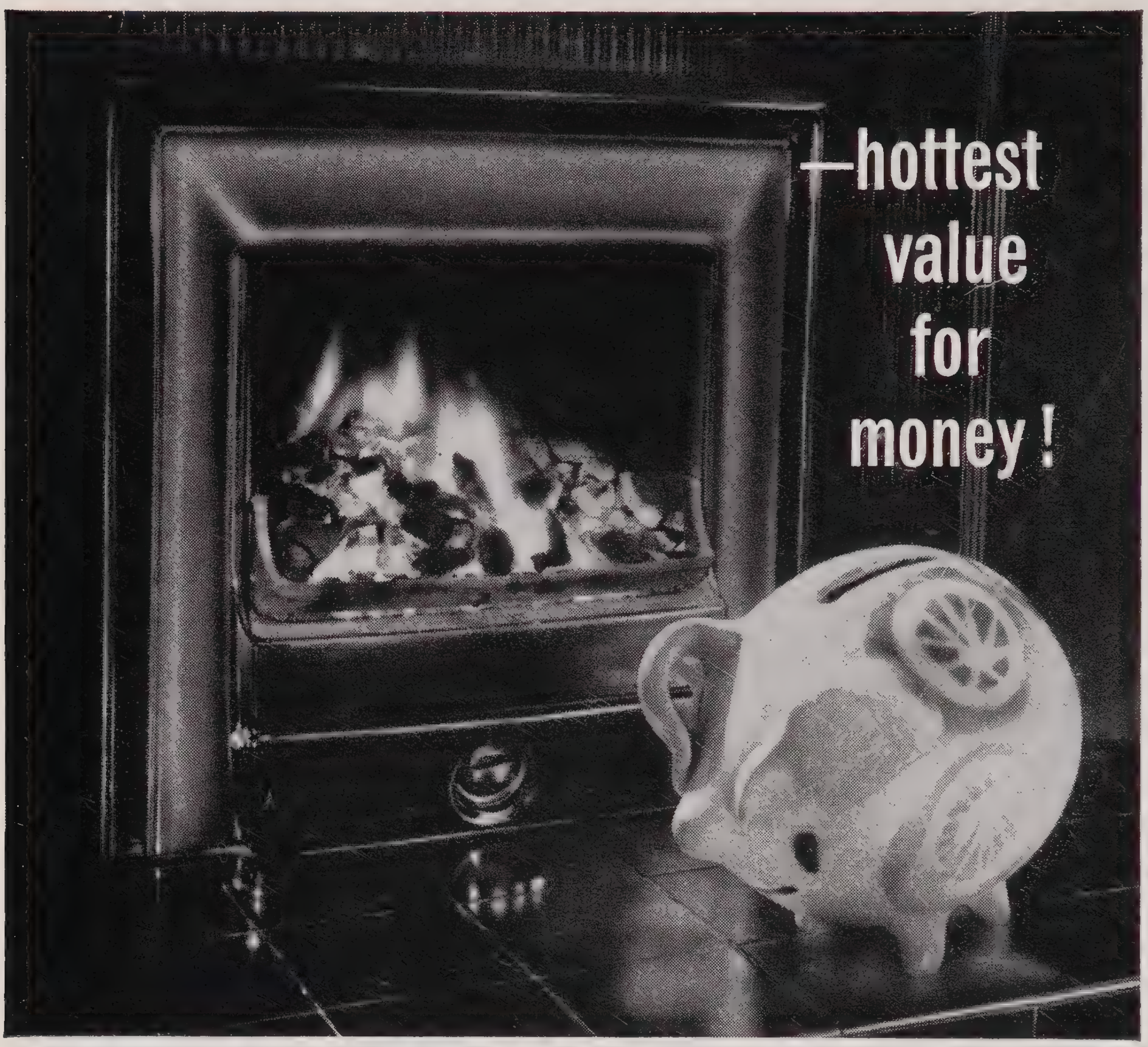
REXCO

gives you more radiant heat



It's the radiant heat of a fire that counts—the heat actually thrown out to warm you. Rexco gives you more radiant heat than any other fuel, weight for weight. That's why it is the hottest value for money.

What's more, Rexco is clean coal; it lasts longer; and it does not dirty your curtains and furnishings.

Always ask your coal merchant for Rexco Smokeless Coal; and Rexco Nuts for your closed stove or boiler.

REXCO SMOKELESS COAL

NATIONAL CARBONISING COMPANY LTD. MANSFIELD, NOTTS.

For Local Authorities promoting

★ ★ ★ ★ ★ ★ ★ CLEAN AIR

SMOKE CONTROL AREAS

The Solid Smokeless Fuels Federation is a non-commercial organisation, its work being educational and advisory. It is one of the organisations listed in the Ministry of Housing and Local Government memorandum on Smoke Control Areas from whom advice can be obtained on suitable appliances, their correct installation and proper operation, and the correct type of smokeless fuel to be used in Smoke Control Areas established by local authorities under the Clean Air Act.

For further information and examples of the full range of free informative literature, apply to:

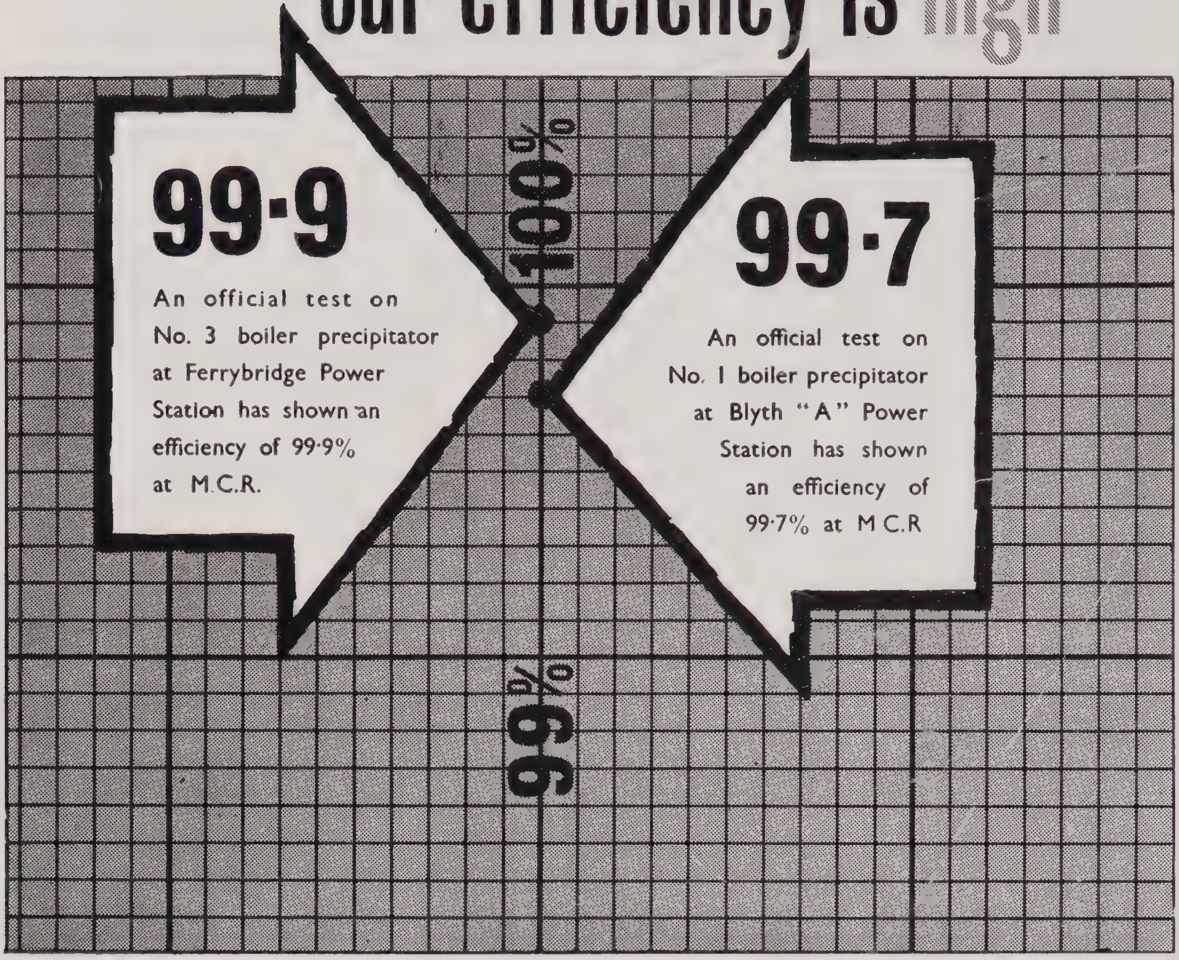
Under the Clean Air Act, powers are given to local authorities to arrange for Clean Air Exhibitions, etc., and to promote educational campaigns to get public support in abolishing smoke and air pollution. Services of this kind have been provided for local authorities by the S.S.F.F. since its formation in 1944. The federation has either organised or participated in Clean Air campaigns up and down the country. The S.S.F.F. exhibition stand and two mobile exhibition units displaying the full range of solid smokeless fuels, and approved appliances actually burning the fuels, are prominent features of these campaigns.

SOLID SMOKELESS FUELS FEDERATION
74 Grosvenor Street, London, W.1. *MAYfair 3327*

SSFF

★ VISIT US AT STAND No. D.2 ★

our efficiency is high



99·9

An official test on No. 3 boiler precipitator at Ferrybridge Power Station has shown an efficiency of 99·9% at M.C.R.

99·7

An official test on No. 1 boiler precipitator at Blyth "A" Power Station has shown an efficiency of 99·7% at M.C.R

With acknowledgements to the Central Electricity Generating Board and Messrs. Babcock & Wilcox Ltd.

Lodge-Cottrell

WHO ARE THE PIONEERS OF ELECTROSTATIC PRECIPITATION

Maintain a high standard of design and performance with Electrostatic Precipitators for the removal of dust and mist from all types of gases.

Consult us on your Gas Cleaning and Dust Emission Problems

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ACIDIC SMUT EMISSION AND SULPHUR FUMES

from

boilers operating on residual fuel oils

ARE BEING ALLEVIATED

simply and economically by treating the fuel oil with

DESULFUROL

The New

SULPHUR INHIBITOR *and* RESIDUAL FUEL OIL IMPROVER

As supplied to oil-fired boiler installations of the Services, Ministries, Municipal Authorities, Hospitals and commercial and industrial concerns.

Details from:

COMBUSTION CHEMICALS LTD

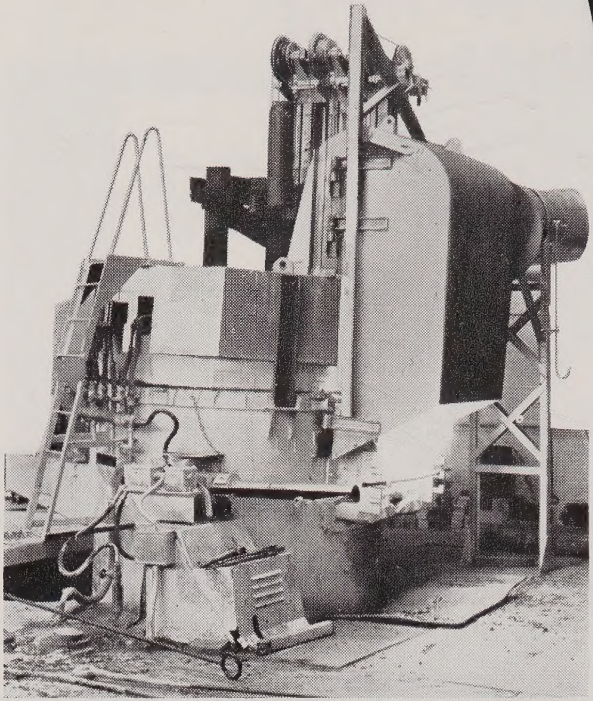
Head Office: **33 DORSET SQUARE, LONDON, N.W.1**

Tel: PADdington 2893 5761 5954

Also suppliers of Combustion Additives in powder form to oil-fired Power Stations of the C.E.G.B. for the control of acidic smut emission and the alleviation of sulphur corrosion

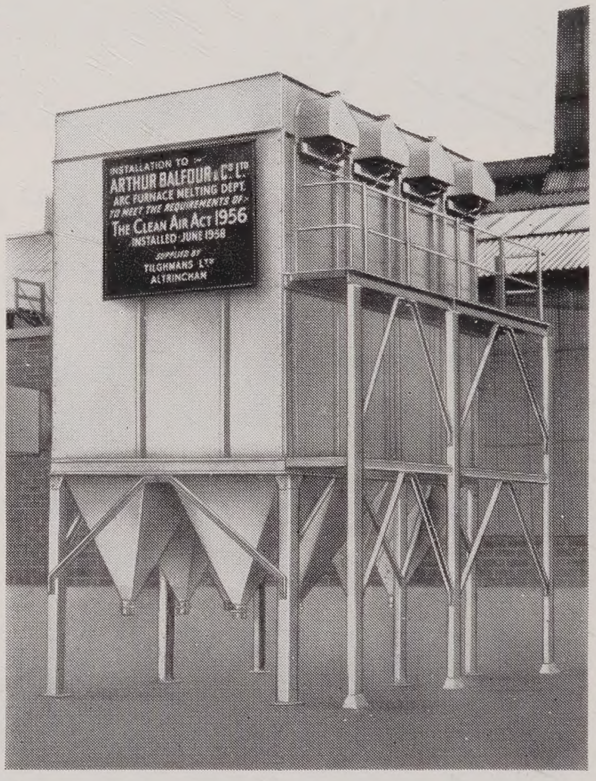
Stand K2

TILGHMAN'S
LIMITED



For a full range of dust collector installations serving all industries, visit our stand where our design engineers will be pleased to discuss your particular problem.

Hot Iron oxide fumes emitted from the furnace during oxygen lancing are drawn off by a specially designed hood to suit the operation of an electric furnace installed at Messrs. Arthur Balfour & Co. Ltd., Sheffield.



The fumes are collected by a Tilghman's Automatic Fabric Filter giving a perfectly clean discharge to the atmosphere, thus complying with the Clean Air Act 1956.

TILGHMAN'S LIMITED

BROADHEATH · ALTRINCHAM · CHESHIRE

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T260

★ *Clean Air* ★

WITH

HARD COKE

THE AUTHORISED SMOKELESS FUEL
MADE BY THE BRITISH COKING INDUSTRY

Hard Coke has outstanding advantages for approved continuous-burning appliances. Users prefer it because it is economical, consistent in quality and free from stone and shale.

The new booklet
'MODERNISE with HARD COKE'

This booklet illustrates and describes a range of typical modern high-efficiency smokeless solid fuel appliances and gives full information on the advantages and most efficient use of Hard Coke. Free on application.

For advice or information on the domestic or industrial use of Hard Coke, apply to the

BRITISH COKING INDUSTRY ASSOCIATION, 74 GROSVENOR ST., LONDON, W.I. *Tel: MAYfair 9736*

DUST PARTICLES KNOW NO BOUNDARIES

There are countless numbers of them waiting to invade your premises, to damage valuable equipment, to pollute the atmosphere and to deposit their grime on furniture, windows and paintwork. Everyone suffers equally in this matter although we may not all offend to the same degree.

Dust control is becoming even more important to-day because of the ever increasing number of industrial plants in operation. Each type of dust has its own physical, chemical and electrical properties and to design dust collection equipment to catch these particles requires basic knowledge of the importance of these variables to the overall problem.

PRAT-DANIELS (STROUD) LTD. is experienced in the measurement of all dust properties. This ability, plus the most advanced design of both mechanical and electrostatic dust collectors, makes Prat-Daniels (Stroud) Ltd. the logical choice to solve your dust collection problems.

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WHITECROFT · NAILSWORTH · STROUD · GLOUCESTERSHIRE

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